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A STUDY OF THE FILTERS USED IN THE DUST RESEARCH PROGRAM AT THE CAPE BRETON COAL RESEARCH LABORATORY

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by

G.R. Corbett*

ABSTRACT

This paper documents the various aspects of gravimetric measuring techniques used to determine the weight of respirable dust on various types of filters and substrates.

It points out various filter characteristics and anomolies, and suggests some correction methods.

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ÉTUDE SUR LES FILTRES UTILISÉS DANS LE CADRE DU PROGRAMME DE RECHERCHE SUR LA POUSSIÈRE AU LABORATOIRE DE RECHERCHE SUR LE CHARBON DU CAP-BRETON

par

G.R. Corbett*

RÉSUMÉ

L'auteur documente les divers aspects des techniques de gravimétrie employées pour déterminer le poids de la poussière respirable sur divers types de filtres et de substrats.

Il signale diverses caractéristiques et anomalies des filtres, puis il suggère certaines méthodes de correction.

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INTRODUCTION

The respirable dust research program of the Cape Breton Coal Research Laboratory (CBCRL), previously described (1), has the long-term objective of attempting to lower the exposure of coal miners to airborne respirable dust and thus reduce the risk of the development of progressive pulmonary disease. The short-term objectives are:

a) Measure respirable dust and total dust at a variety of locations and conditions in the Cape Breton Development Corporation's (CBDC) underground coal mines.
b) Identify and quantify major dust sources in the mines.
c) Correlate longwall face workers' personal exposure to control point measurements.

These objectives can only be met when recognized procedures are followed both in the laboratory and at the trial site. In order to obtain accurate gravimetric weights of dust samples deposited on filters of various types, it is necessary to identify the conditions which most affect the filter types used. Filters of different composition react differently when subjected to various conditions of static electricity, humidity, handling and transportation.

This document qualifies and quantifies differences in various filter media used in the CBCRL dust research program. It also may be used as a guide to the techniques which should be used when attempting to make accurate gravimetric analyses when very little sample, i.e. less than 5 mg, is present.

FILTRATION MEDIA

The objective of filtration is to achieve a clean fluid/gas or to extract, in order to analyse, matter separated from the fluid/gas by the filter. Filtration media is catagorized into one of two main types: depth filters and screen media or membrane filters.

Table 1 - Instrumentation

Mettler AE-163, Semi-microbalance, 30 g ±0.00001 g
Cahn 29, Microbalance, .250 g ±0.000001 g
Cahn 10034, Balance accessories and calibration weights
EC-307, Stopwatch Calculator
Aneroid Barrometer
Mercury Barrometer
Thies Aspirating Cycrometer, ±1°C on both scales
Static Master 2U500, Ionizing Unit
Electrahome EHR10 Humidifier, delivery 1.5 1/hr
Electrahome EDP30 Dehumidifier, recovery 1.25 1/hr
Carrier 51KW1061 Air Conditioner, 6000 btu/hr
Various petri dishes and glassware
Weighing room with no outside ventilation

Table 2 - Common media used in gravimetric analysis of coal mine dust

Composition	Diameter Used (mm)	Pore Size (microns)	Type
Fiberglass	25, 37, 55	1.5, 1.6 Nominal	Depth
Polyvinyl Chloride (PVC)	25, 37	0.8, 5.0 Actual	Screen
Nuclepore (Polycarbonate)	25, 37	0.8, 5.0 Actual	Screen
Membrafil, Millipore (Mixed Esters of Cellulose)	25, 37, 55	0.8 Actual	Screen
Silver Membrane	25, 37, 55	0.8, 0.45 Actual	Screen
Polymers (Teflon, Nylon)	Full Range	Full Range	Screen
Substrates: For Marple 298 Cascade Impactor			
Mylar (Polymer)	35	N/A	N/A
Stainless Steel	35	N/A	N/A

Depth filters derive their name from filtration which occurs within the random maze of flow channels which make up the filter media. Because of this, there is no defined pore structure and it is not possible to quantitatively state relative characteristics by size. A depth filter is given a nominal rating, determined experimentally, and will retain 98% of all particles greater than that rating.

Screen filters or membrane filters retain particles on their surface by physically screening them from the solution or gas. Retention takes place only on the surface and hence the name screen filters. The structure of this type of filter is more uniform and pore size is known precisely. Because pore size is known precisely, it is possible to quantify the retention of particles by size.

The filters listed in Table 2 are those used by CBCRL for gravimetric determination of respirable and total dust. A brief description of each filter's characteristics is given. This list is by no means complete as filter technology is growing and new filter types are being developed. This table represents some of the more widely used filters in the gravimetric analysis of coal dust.

DESCRIPTION OF FILTER TYPES

FIBERGLASS

Fiberglass filters are depth filters with no actual pore size but have a nominal pore size determined experimentally. They can be used at high flow rates and are high loading capacity filters. Some disadvantages are its problems with absorption of liquid thereby causing erroneous results in gravimetric analysis. Filter material tends to stick to the holder and this is another source of error. Filters of this type are inferior when analysis of quartz or silica is required because of the very high background counts. Because they are depth filters, a great portion of the particles sampled are immersed within the filter matrix and therefore do not lend themselves to light or electron microscopy if identification of constituents are needed.

Under properly controlled environmental conditions, these filters are excellent candidates for determining the gravimetric weight of a

sample but where composition of the sample is needed, a screen filter should be used.

POLYVINYL CHLORIDE (PVC)

PVC filters are screen filters with a precisely known pore size. They exhibit extremely low absorption of water making them ideal for gravimetric analysis. They have very low background interference for sample analysis by X-ray diffraction and they lend themselves to analysis by certain types of microscopy.

The main drawback of the PVC filter is their susceptibility to static charges which causes problems with handling the filter to the extent that a loss of the sample can occur. Extreme care and precaution must be taken into account when using this filter type to determine the weight of a sample deposited on this filter.

POLYCARBONATE

Polycarbonate filters are screen filters with a precisely known pore size. Particle size retention can therefore be calculated precisely. Filters of this type are good candidates for trace element analysis or analysis by scanning electron or optical microscopy. They are flexible, strong and do not tear easily. This flexibility makes the polycarbonate filter extremely difficult to handle. Getting the filter on and off the balance pan is difficult without losing deposited particles. Polycarbonate filters are also prone to static charges and are affected by laboratory conditions to a lesser extent. This filter type is good for gravimetric analysis when handled properly and under controlled environmental conditions.

MIXED CELLULOSE OF ESTERS (MILLIPORE AND MEMBRAFIL)

This screen filter, sometimes referred to as cellulosic membrane, has a precisely known pore size. It is high performance in that high flow rates are enabled due to the fact that pores account for about 80% of the filter volume. It has excellent surface retention thereby making particulates readily available to enumeration analysis. This filter is somewhat chemically resistant and may be optically cleared using select organic solvents, so that viewing of the particles by various light microscopy methods is possible. The filter material may be ashed away by a low-temperature

plasma asher or in a conventional oven at approximately 800°-900° centigrade with little or no residual filter weight. It lends itself very well to analysis by X-ray diffraction and electron microscopy. Some static problems are evident but controllable and errors due to handling are minimal due to the filter's rigidity.

The major drawback to using cellulosic membrane filters are their susceptibility to the environmental conditions. Changes in humidity and temperature must be kept in check to obtain reliable results.

SILVER MEMBRANE

The silver membrane filter is a screen filter of pure silver. This makes the filter heavy in comparison with other micro-filters and therefore consideration must be given to the balance being used to weigh the filter. Silver membrane, because of its low background silica count and high atomic weight, is the best filter to use when analysis of the sample by X-ray diffraction is required, especially if crystalline silica is the substance being analysed for. This filter is solvent resistant, exhibits excellent handling properties and is unaffected by static electricity or environmental changes like humidity or temperature. This filter is excellent for gravimetric analysis but is costly.

POLYMERS (TEFLON, NYLON, ETC.)

Very little work has been done with these filters in the CBCRL dust program, but the minimal work which has been undertaken shows that they are screen filters worthy of further investigation. These types of materials are available in all pore sizes and exhibit excellent handling properties, which make them ideal for use in gravimetric analysis.

SUBSTRATES

Substrates are not filters but surface collectors used in the various stages of a cascade impactor. A cascade impactor is a device used to separate the various sizes of dust from each other by using a series of impaction plates on which the treated substrate is placed. The dust laden air containing all the sizes of dust is drawn into the impactor inlet and is forced to either turn into the next inlet or smash or impact onto the treated substrate held on the impaction plate. Whether the dust particle impacts or

continues to the next plate is directly related to its size, therefore the different fractions or sizes of respirable dust may be collected on a series of impactor substrates.

Substrates are usually inert materials, mylar (polymer) or stainless steel, which are coated with an impaction grease that acts to hold the sample to the substrate once impaction has taken place. Substrates provide excellent media for gravimetric analysis, are unaffected by static or conditions of changing humidity and pose little or no handling problems.

Cascade impactors provide reliable data on the sizes of the components of respirable coal mine dust. Preliminary results of cascade impactor use has been documented (3) and a further report is planned.

TRIALS AND PROCEDURES

As is described in the previous pages, each filter has its definite advantages and disadvantages, so selecting the proper filter to do all jobs is difficult. First, the job in question must be identified. If gravimetric identification is all that is needed, then a fiberglass or PVC filter would prove the least costly and certainly the best in performance. However, PVC filters are very prone to static electricity and sample could be lost from the filter. On the other hand the fiberglass filter does not allow for analysis of silica, which is a chief concern in identifying factors related to incidence of pulmonary disease.

The cellulosic filter exhibits excellent potential for analysis of the deposited sample by more than one technique. It is a very good candidate for use in gravimetric analysis under the proper conditions.

The following pages are dedicated to identifying problems involved when using the various types of filters especially cellulosic and fiberglass filters. An attempt is made to point out procedures which will correct any errors which may occur because of these filter's particular reactions toward certain environmental changes.

TRIAL 1

Table 3 is a comparison of blanks used in the CBCRL dust research program. Weights were obtained using procedure 'A' (to follow). It lists

the weight change and corresponding humidity change for initial and final weighing days; for example on survey No. 1 the relative humidity on the initial weighing day was 25% where on the final weighing day it was 23% therefore the humidity change is -2. The millipore blank weight change for the same period was -.046 and the fiberglass blank change was -.001.

PROCEDURE 'A'

Prior to Field Survey or Test

1) Place filters along with the blanks out in the laboratory environment for at least two hours.
2) Calibrate Cahn 29 or suitable electrobalance (follow calibration procedure in balance manual).
3) Obtain the following measurements: wet bulb temperature, dry bulb temperature using aspirating cycrometer.
4) Determine relative humidity and dew point from measurements obtained in 3).
5) Pass each filter through the static master ionizing unit in order to remove any static charges built-up on the filter.
6) Place each filter on the tared balance pan, close the door and start the stopwatch.
7) Take the weight reading at the two minute mark or when the change in the filter weight is ±.001 mg/sec.
8) Upon completion of all weighing, seal blank in containers and place filters in sample holders to be used to determine respirable dust concentration.

Upon Completion of Field Survey or Test

9) Place filters in a dessicator for a minimum of two hours.
10) Repeat steps 1) to 7) to achieve a final weight for filters and samples after the survey is completed.
11) Determine the respirable dust concentrations from the data collected in the previous steps (this is outlined in step 20 of procedure 'C').

DISCUSSION OF PROCEDURE 'A' AND TRIAL 1

It can be seen from Table 3 and the resulting figures that various filters react differently when exposed to different conditions. This is due

Table 3 - Changes between initial and final weighing of blanks for field surveys Nos. 1 to 10

	CHANGES BETWEEN INITIAL AND FINAL WEIGHING OF BLANKS				
SURVEY	AVERAGE CHANGE IN MILLIPORE BLANK WEIGHT (MGS)	AVERAGE CHANGE IN FIBERGLASS BLANK WEIGHT (MGS)	AVERAGE CHANGE IN POLYVINYL CHLORIDE BLANK WT. (MGS)	AVERAGE CHANGE IN POLY-CARBONATE BLANK WT. (MGS)	CHANGE IN RELATIVE HUMIDITY %
1	0.079	0.007		0.001	7
2	-0.046	-0.001			-2
3	-0.021	0.020			1
4	0.004	-0.015			0
5	0.004	-0.004	-0.003	0.002	-2
6	0.024	0.011	-0.006	-0.007	1
7	-0.028	0.046	-0.007	0.003	-1
8	0.048	0.029	0.006	0.006	6
9	0.029	0.014	-0.003	0.004	4
10	0.035	-0.003	0.009	0.006	3

to their make up and factors such as water absorption, static responses and handling properties.

This trial tries to relate the humidity to the weight change which the filter undergoes once placed on the balance pan. This weight change takes place simply because the environment of the balance chamber is different from the laboratory environment, possibly because of low levels of heat emitted from the electronics of the balance.

The polycarbonate and polyvinyl chloride filters seem to be unaffected by this environmental change as far as humidity is concerned. Figures 1C and 1D show that over the humidity range there is no upward or downward trend in blank weight change; therefore, it can be said that the weight change bears no relationship to the humidity change within the range of humidity used. Static charges on both these filters must be minimized and could represent a large error source especially in the case of the PVC filter, whereas the polycarbonate filter exhibits handling problems.

The fiberglass filter, being a depth filter, has water absorption characteristics and once placed on the balance pan starts to give up the water very slowly. It can be seen from Figure 1A that over the humidity range, the fiberglass filter exhibits a positive slope which indicates that as the humidity increases, the weight change is positive and some minimal water absorption takes place.

The millipore filter is an example of rapid equilibration with its environment, i.e. the balance chamber. Water easily absorbes within or on the surface of the mixed cellulose ester filter but the filter will not retain it and easily gives it up. On placing the filter in the warmer balance environment the water immediately begins to evaporate and the weight starts to decrease. The slope of the curve, Figure 1B, is much more positive indicating the increased change in weight over the humidity range used.

TRIAL 2

Trial 2 consists of seven separate sets of data (weighing of four filters on seven separate days). The four filters used were two millipore and two fiberglass. These filters were chosen because they were most often used in the dust research program and as seen from Trial 1, both seem to be affected by humidity, one to a lesser degree than the other. One filter of each type was loaded with a similar quantity of coal dust. The weight change

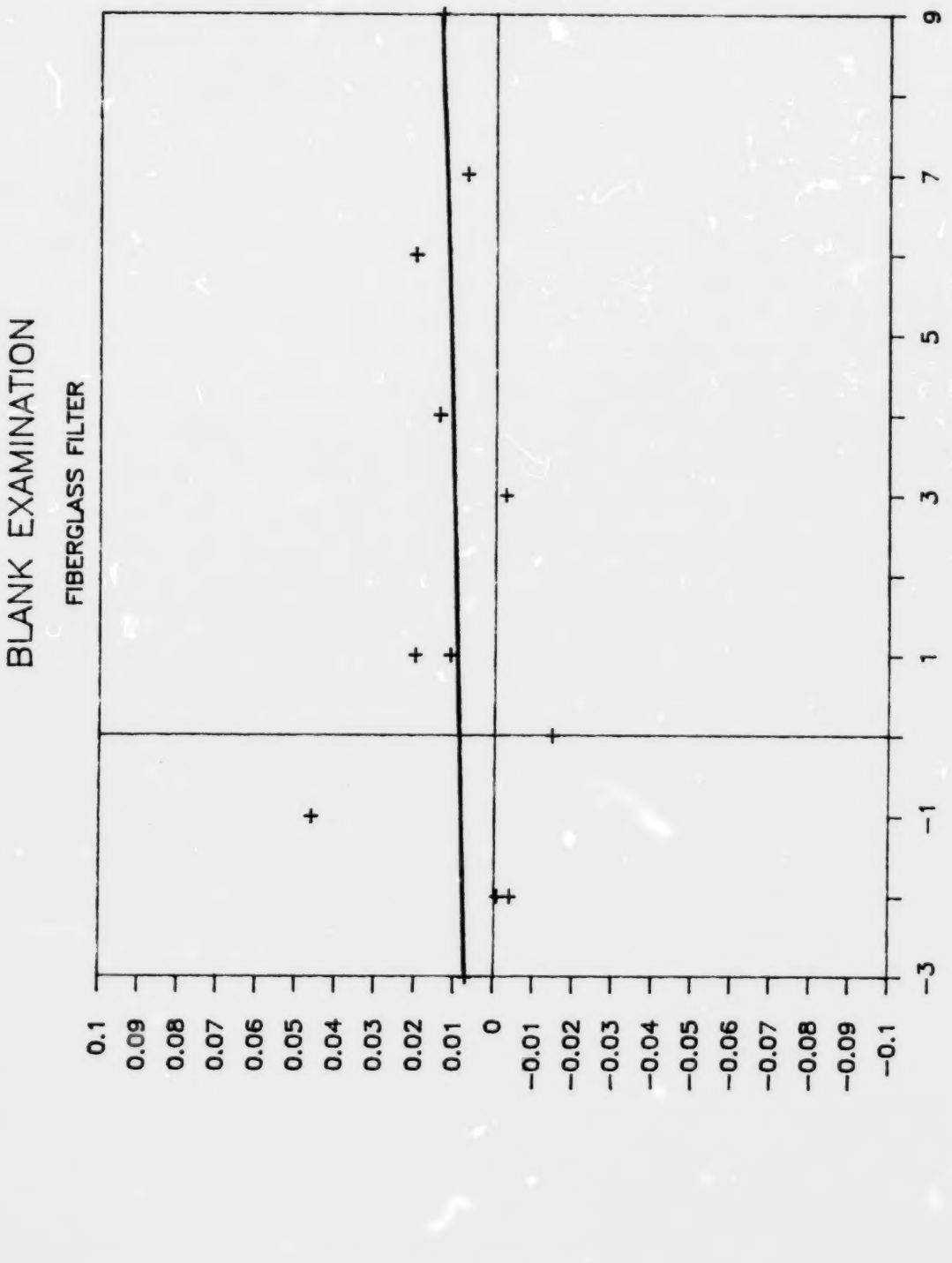


Figure 1A - Trial 1, fiberglass blank examination

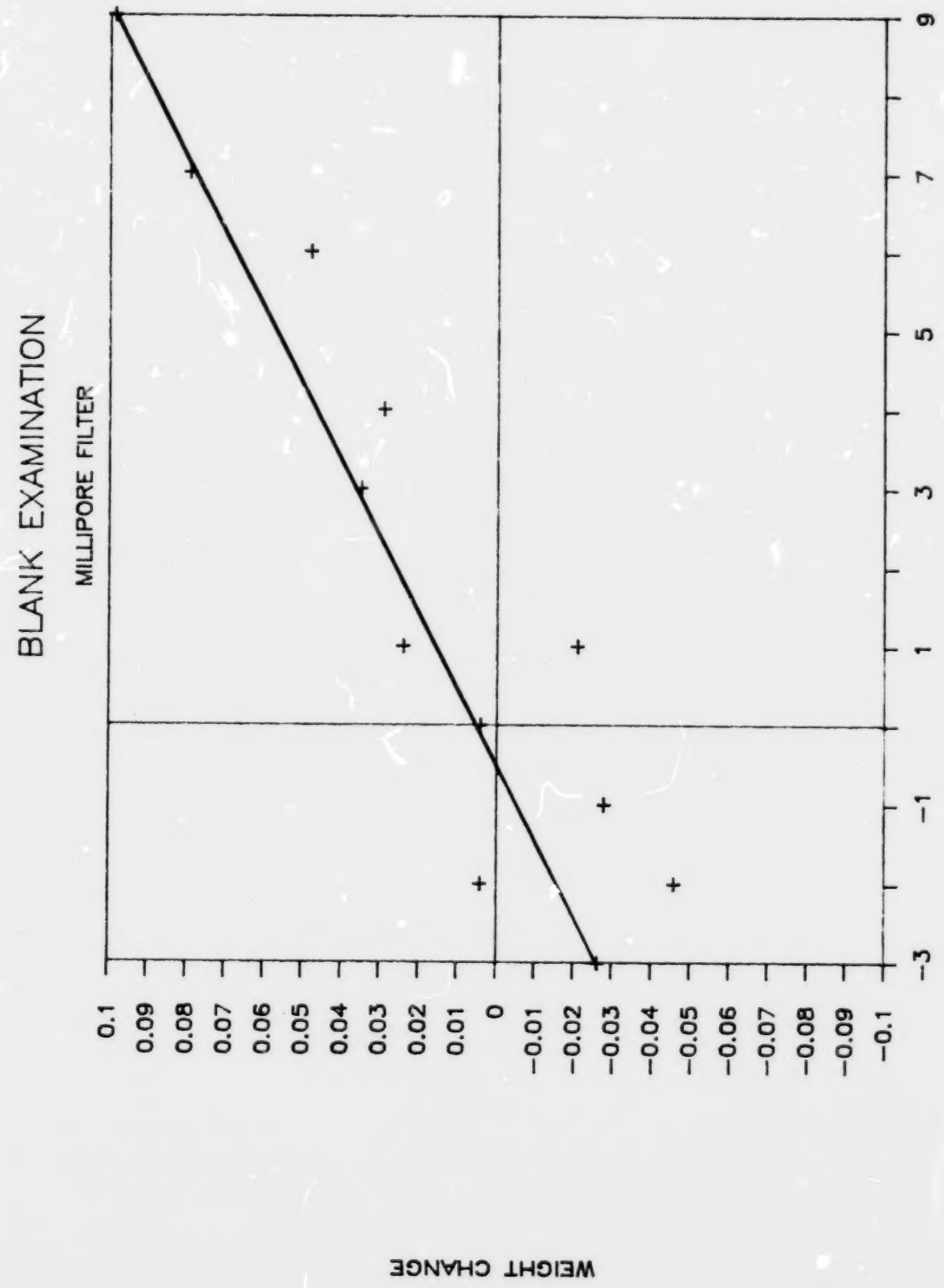


Figure 1B - Trial 1, millipore blank examination

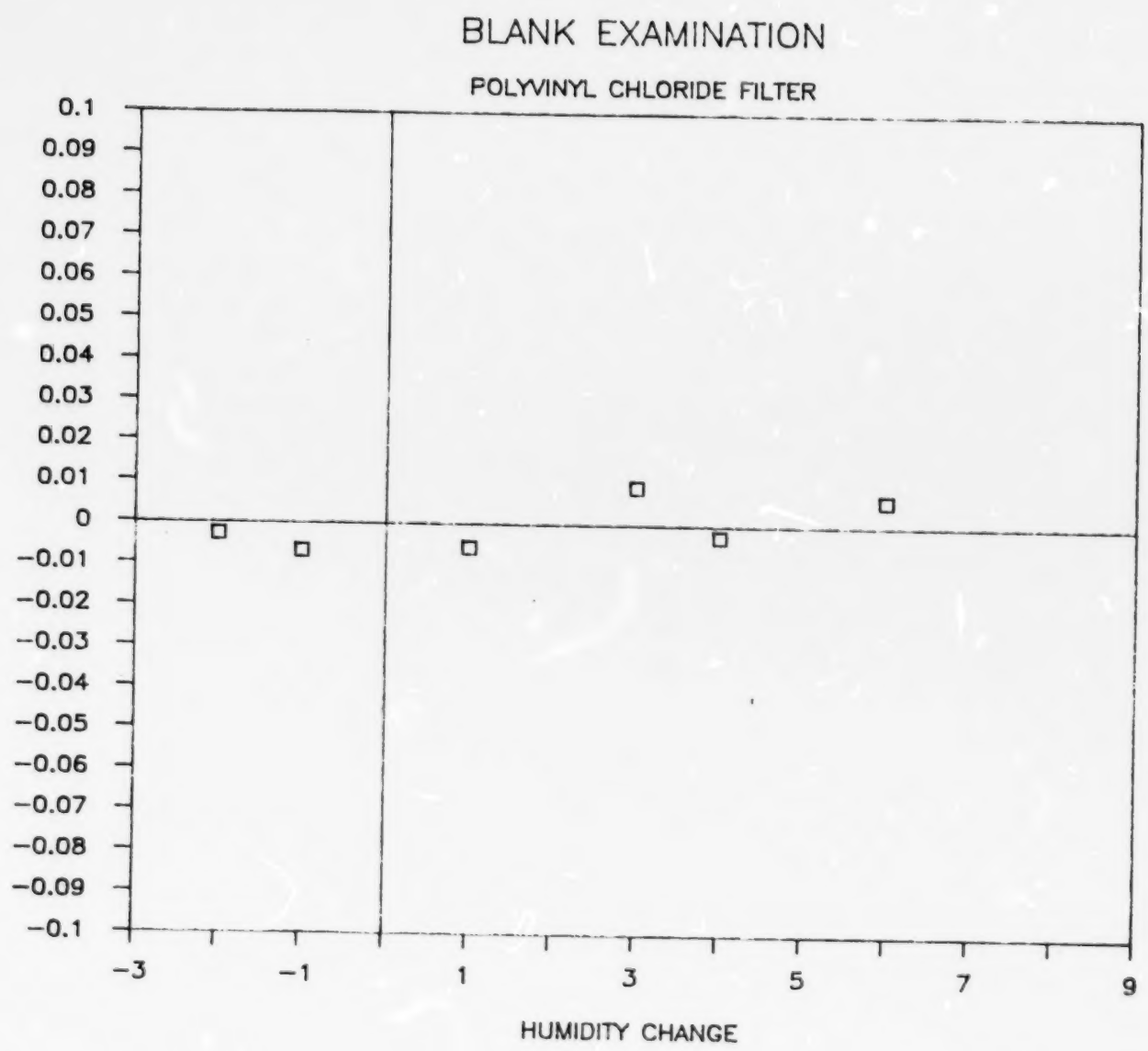


Figure 1C - Trial 1, polyvinyl chloride blank examination

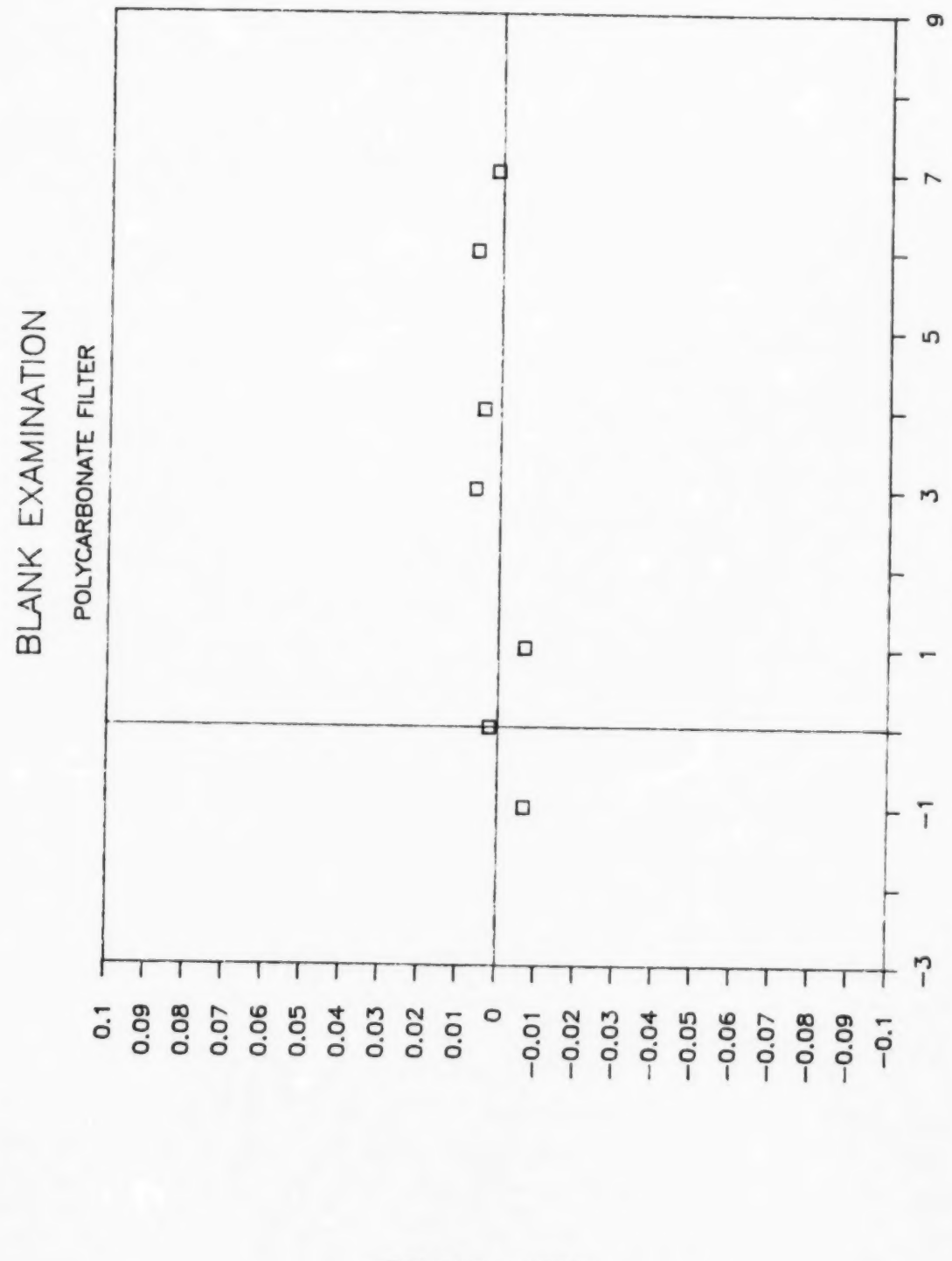


Figure 1D - Trial 1, polycarbonate blank examination

for each filter was noted over a period of time in order to identify any loss or gain while transferring the filters from the laboratory environment to the balance chamber environment. Procedure 'B' was used to determine Table 4 and the results are shown in Figures 2A-2G and resulting discussions.

PROCEDURE 'B' (FOR DAYS 1 TO 7)

1) Follow steps 1) to 6) of Procedure 'A'.
2) Note the weight reading at the 30 second mark and every 30 second interval afterwards up to 10 minutes. Repeat for each of the four filters used.
3) Note all weight changes and construct Table 4 and Figures 2A-2G of cumulative weight change for each filter type.
4) Follow this procedure for seven days (not necessarily in succession) to achieve tables for different environmental conditions.

DISCUSSION OF PROCEDURE 'B' AND TRIAL 2

This trial is intended to give a more detailed view of millipore and fiberglass relationships to relative humidity. It can be seen from Table 4 and Figures 2A-2G that the weight loss or gain is much greater for the millipore filter as compared to the fiberglass filter.

There seems to be no relationship between the weights of the loaded fiberglass filters and empty fiberglass filters. Empty and loaded millipore filters show the same curve of weight change versus humidity but sudden shifts in weight loss as in Figure 2B as apposed to Figures 2A or 2E remain unexplained and need further study.

It can be seen that over the seven days of testing, fiberglass filter weight shifts were insignificant and with a dust sample weight of 1 mg, accounts for only 0.5% error whether considering either the loaded or empty filter. The millipore filter weight shift could account for as much as 8% error on the same sample weight if initial and final filter weights were not taken at the same time interval each time.

The overall point which Table 4 and Figures 2A-2G make is that the millipore filters are easily climatized and rapidly move towards equilibrium as compared to the fiberglass filters which remain more stable for longer periods of time. In order to characterize these filter types better, a wider

Table 4 - Comparison of millipore and fiberglass filters over seven (7) days

DAY 1	WET BULB (deg C) 11.9	DRY BULB (deg C) 22.1
	RELATIVE HUMIDITY (%) 26.0	DEW POINT (deg C) 2.0

FILTER	EMPTY MILLIPORE (EM)			LOADED MILLIPORE (LM)			EMPTY FIBERGLASS (EF)			LOADED FIBERGLASS (LF)		
ELAPSED TIME (sec)	WEIGHT (mgs)	WEIGHT CHANGE	CUMULATIVE CHANGE	WEIGHT (mgs)	WEIGHT CHANGE	CUMULATIVE CHANGE	WEIGHT (mgs)	WEIGHT CHANGE	CUMULATIVE CHANGE	WEIGHT (mgs)	WEIGHT CHANGE	CUMULATIVE CHANGE
30	49.067	0.000	0.000	54.049	0.000	0.000	70.083	0.000	0.000	72.076	0.000	0.000
60	49.043	-0.024	-0.024	54.029	-0.020	-0.020	70.081	-0.002	-0.002	72.076	0.000	0.000
90	49.031	-0.012	-0.036	54.021	-0.008	-0.028	70.081	0.000	-0.002	72.076	0.000	0.000
120	49.024	-0.007	-0.043	54.015	-0.006	-0.034	70.081	0.000	-0.002	72.076	0.000	0.000
150	49.018	-0.006	-0.049	54.010	-0.005	-0.039	70.081	0.000	-0.002	72.076	0.000	0.000
180	49.013	-0.005	-0.054	54.006	-0.004	-0.043	70.081	0.000	-0.002	72.075	-0.001	-0.001
210	49.009	-0.004	-0.058	54.003	-0.003	-0.046	70.080	-0.001	-0.003	72.075	0.000	-0.001
240	49.005	-0.004	-0.062	53.999	-0.004	-0.050	70.080	0.000	-0.003	72.074	-0.001	-0.002
270	49.002	-0.003	-0.065	53.996	-0.003	-0.053	70.080	0.000	-0.003	72.075	0.001	-0.001
300	49.000	-0.002	-0.067	53.994	-0.002	-0.055	70.080	0.000	-0.003	72.074	-0.001	-0.002
330	48.998	-0.002	-0.069	53.992	-0.002	-0.057	70.080	0.000	-0.003	72.074	0.000	-0.002
360	48.996	-0.002	-0.071	53.990	-0.002	-0.059	70.080	0.000	-0.003	72.074	0.000	-0.002
390	48.994	-0.002	-0.073	53.988	-0.002	-0.061	70.080	0.000	-0.003	72.074	0.000	-0.002
420	48.992	-0.002	-0.075	53.986	-0.002	-0.063	70.080	0.000	-0.003	72.074	0.000	-0.002
450	48.991	-0.001	-0.076	53.985	-0.001	-0.064	70.080	0.000	-0.003	72.074	0.000	-0.002

DAY 2	WET BULB (deg C) 11.6	DRY BULB (deg C) 27.3
	RELATIVE HUMIDITY (%) 18.0	DEW POINT (deg C) -2.0

FILTER	EMPTY MILLIPORE (EM)			LOADED MILLIPORE (LM)			EMPTY FIBERGLASS (EF)			LOADED FIBERGLASS (LF)		
ELAPSED TIME (sec)	WEIGHT (mgs)	WEIGHT CHANGE	CUMULATIVE CHANGE	WEIGHT (mgs)	WEIGHT CHANGE	CUMULATIVE CHANGE	WEIGHT (mgs)	WEIGHT CHANGE	CUMULATIVE CHANGE	WEIGHT (mgs)	WEIGHT CHANGE	CUMULATIVE CHANGE
30	49.052	0.000	0.000	54.014	0.000	0.000	70.076	0.000	0.000	72.082	0.000	0.000
60	49.039	-0.013	-0.013	53.991	-0.023	-0.023	70.077	0.001	0.001	72.083	0.001	0.001
90	49.028	-0.011	-0.024	53.980	-0.011	-0.034	70.077	0.000	0.001	72.083	0.000	0.001
120	49.019	-0.009	-0.033	53.973	-0.007	-0.041	70.077	0.000	0.001	72.083	0.000	0.001
150	49.012	-0.007	-0.040	53.968	-0.005	-0.046	70.076	-0.001	0.000	72.083	0.000	0.001
180	49.005	-0.007	-0.047	53.964	-0.004	-0.050	70.076	0.000	0.000	72.082	-0.001	0.000
210	49.000	-0.005	-0.052	53.960	-0.004	-0.054	70.076	0.000	0.000	72.082	0.000	0.000
240	48.995	-0.005	-0.057	53.958	-0.002	-0.056	70.076	0.000	0.000	72.082	0.000	0.000
270	48.991	-0.004	-0.061	53.955	-0.003	-0.059	70.075	-0.001	-0.001	72.082	0.000	0.000
300	48.987	-0.004	-0.065	53.953	-0.002	-0.061	70.075	0.000	-0.001	72.081	-0.001	-0.001
330	48.984	-0.003	-0.068	53.952	-0.001	-0.062	70.075	0.000	-0.001	72.081	0.000	-0.001
360	48.981	-0.003	-0.071	53.950	-0.002	-0.064	70.075	0.000	-0.001	72.081	0.000	-0.001
390	48.978	-0.003	-0.074	53.949	-0.001	-0.065	70.075	0.000	-0.001	72.081	0.000	-0.001
420	48.976	-0.002	-0.076	53.948	-0.001	-0.066	70.075	0.000	-0.001	72.081	0.000	-0.001
450	48.974	-0.002	-0.078	53.947	-0.001	-0.067	70.075	0.000	-0.001	72.081	0.000	-0.001
480	48.972	-0.002	-0.080	53.946	-0.001	-0.068	70.075	0.000	-0.001	72.081	0.000	-0.001
510	48.970	-0.002	-0.082	53.945	-0.001	-0.069	70.075	0.000	-0.001	72.081	0.000	-0.001
540	48.968	-0.002	-0.084	53.945	0.000	-0.069	70.075	0.000	-0.001	72.081	0.000	-0.001
570	48.967	-0.001	-0.085	53.944	-0.001	-0.070	70.075	0.000	-0.001	72.081	0.000	-0.001

Table 4 - Continued

DAY 3	WET BULB (deg C) 14.4	DRY BULB (deg C) 24.4
	RELATIVE HUMIDITY (%) 31.0	DEW POINT (deg C) 6.0

FILTER	EMPTY MILLIPORE (EM)			LOADED MILLIPORE (LM)			EMPTY FIBERGLASS (EF)			LOADED FIBERGLASS (LF)		
ELAPSED TIME (sec)	WEIGHT (ugs)	WEIGHT CHANGE	CUMULATIVE CHANGE	WEIGHT (ugs)	WEIGHT CHANGE	CUMULATIVE CHANGE	WEIGHT (ugs)	WEIGHT CHANGE	CUMULATIVE CHANGE	WEIGHT (ugs)	WEIGHT CHANGE	CUMULATIVE CHANGE
30	49.125	0.000	0.000	54.125	0.000	0.000	70.072	0.000	0.000	71.464	0.000	0.000
60	49.115	-0.010	-0.010	54.112	-0.013	-0.013	70.078	0.006	0.006	71.466	0.002	0.002
90	49.109	-0.006	-0.016	54.107	-0.005	-0.018	70.078	0.000	0.006	71.466	0.000	0.002
120	49.105	-0.004	-0.020	54.105	-0.002	-0.020	70.078	0.000	0.006	71.465	-0.001	0.001
150	49.101	-0.004	-0.024	54.103	-0.002	-0.022	70.078	0.000	0.006	71.465	0.000	0.001
180	49.098	-0.003	-0.027	54.103	0.000	-0.022	70.078	0.000	0.006	71.464	-0.001	0.000
210	49.096	-0.002	-0.029	54.101	-0.002	-0.024	70.078	0.000	0.006	71.465	0.001	0.001
240	49.094	-0.002	-0.031	54.100	-0.001	-0.025	70.078	0.000	0.006	71.464	-0.001	0.000
270	49.092	-0.002	-0.033	54.099	-0.001	-0.026	70.078	0.000	0.006	71.464	0.000	0.000
300	49.090	-0.002	-0.035	54.099	0.000	-0.026	70.078	0.000	0.006	71.464	0.000	0.000
330	49.088	-0.002	-0.037	54.098	-0.001	-0.027	70.078	0.000	0.006	71.464	0.000	0.000
360	49.087	-0.001	-0.038	54.097	-0.001	-0.028	70.078	0.000	0.006	71.464	0.000	0.000
390	49.086	-0.001	-0.039	54.097	0.000	-0.028	70.078	0.000	0.006	71.464	0.000	0.000
420	49.085	-0.001	-0.040	54.096	-0.001	-0.029	70.078	0.000	0.006	71.464	0.000	0.000
450	49.084	-0.001	-0.041	54.096	0.000	-0.029	70.078	0.000	0.006	71.464	0.000	0.000
480	49.083	-0.001	-0.042	54.095	-0.001	-0.030	70.078	0.000	0.006	71.464	0.000	0.000
510	49.082	-0.001	-0.043	54.095	0.000	-0.030	70.078	0.000	0.006	71.464	0.000	0.000
540	49.081	-0.001	-0.044	54.095	0.000	-0.030	70.078	0.000	0.006	71.464	0.000	0.000
570	49.081	0.000	-0.044	54.094	-0.001	-0.031	70.078	0.000	0.006	71.464	0.000	0.000

DAY 4	WET BULB (deg C) 12.8	DRY BULB (deg C) 25.2
	RELATIVE HUMIDITY (%) 20.0	DEW POINT (deg C) 0.0

FILTER	EMPTY MILLIPORE (EM)			LOADED MILLIPORE (LM)			EMPTY FIBERGLASS (EF)			LOADED FIBERGLASS (LF)		
ELAPSED TIME (sec)	WEIGHT (ugs)	WEIGHT CHANGE	CUMULATIVE CHANGE	WEIGHT (ugs)	WEIGHT CHANGE	CUMULATIVE CHANGE	WEIGHT (ugs)	WEIGHT CHANGE	CUMULATIVE CHANGE	WEIGHT (ugs)	WEIGHT CHANGE	CUMULATIVE CHANGE
30	49.026	0.000	0.000	54.024	0.000	0.000	70.066	0.000	0.000	71.456	0.000	0.000
60	49.013	-0.013	-0.013	54.013	-0.011	-0.011	70.068	0.002	0.002	71.460	0.004	0.004
90	49.006	-0.007	-0.020	54.008	-0.005	-0.016	70.068	0.000	0.002	71.460	0.000	0.004
120	49.001	-0.005	-0.025	54.005	-0.003	-0.019	70.067	-0.001	0.001	71.460	0.000	0.004
150	48.997	-0.004	-0.029	54.002	-0.003	-0.022	70.068	0.001	0.002	71.460	0.000	0.004
180	48.994	-0.003	-0.032	54.000	-0.002	-0.024	70.067	-0.001	0.001	71.460	0.000	0.004
210	48.992	-0.002	-0.034	53.998	-0.002	-0.026	70.067	0.000	0.001	71.460	0.000	0.004
240	48.989	-0.003	-0.037	53.996	-0.002	-0.028	70.067	0.000	0.001	71.460	0.000	0.004
270	48.988	-0.001	-0.038	53.994	-0.002	-0.030	70.067	0.000	0.001	71.460	0.000	0.004
300	48.986	-0.002	-0.040	53.993	-0.001	-0.031	70.067	0.000	0.001	71.460	0.000	0.004
330	48.984	-0.002	-0.042	53.992	-0.001	-0.032	70.067	0.000	0.001	71.460	0.000	0.004
360	48.983	-0.001	-0.043	53.990	-0.002	-0.034	70.067	0.000	0.001	71.460	0.000	0.004
390	48.982	-0.001	-0.044	53.988	-0.002	-0.036	70.067	0.000	0.001	71.460	0.000	0.004
420	48.980	-0.002	-0.046	53.987	-0.001	-0.037	70.067	0.000	0.001	71.460	0.000	0.004
450	48.980	0.000	-0.046	53.987	0.000	-0.037	70.067	0.000	0.001	71.460	0.000	0.004
480	48.979	-0.001	-0.047	53.986	-0.001	-0.038	70.067	0.000	0.001	71.460	0.000	0.004
510	48.978	-0.001	-0.048	53.986	0.000	-0.038	70.067	0.000	0.001	71.460	0.000	0.004
540	48.977	-0.001	-0.049	53.985	-0.001	-0.039	70.067	0.000	0.001	71.460	0.000	0.004
570	48.976	-0.001	-0.050	53.985	0.000	-0.039	70.067	0.000	0.001	71.460	0.000	0.004

Table 4 - Continued

DAY 5 — WET BULB (deg C) 13.2 — DRY BULB (deg C) 24.0 — RELATIVE HUMIDITY (%) 26.0 — DEW POINT (deg C) 3.0

ELAPSED TIME (sec)	EMPTY MILLIPORE (EM) WEIGHT (mgs)	EM WEIGHT CHANGE	EM CUMULATIVE CHANGE	LOADED MILLIPORE (LM) WEIGHT (mgs)	LM WEIGHT CHANGE	LM CUMULATIVE CHANGE	EMPTY FIBERGLASS (EF) WEIGHT (mgs)	EF WEIGHT CHANGE	EF CUMULATIVE CHANGE	LOADED FIBERGLASS (LF) WEIGHT (mgs)	LF WEIGHT CHANGE	LF CUMULATIVE CHANGE
30	49.107	0.000	0.000	54.060	0.000	0.000	70.067	0.000	0.000	71.457	0.000	0.000
60	49.091	-0.016	-0.016	54.049	-0.011	-0.011	70.070	0.003	0.003	71.462	0.005	0.005
90	49.078	-0.013	-0.029	54.045	-0.004	-0.015	70.070	0.000	0.003	71.462	0.000	0.005
120	49.069	-0.009	-0.038	54.043	-0.002	-0.017	70.070	0.000	0.003	71.463	0.001	0.006
150	49.063	-0.006	-0.044	54.041	-0.002	-0.019	70.070	0.000	0.003	71.463	0.000	0.006
180	49.057	-0.006	-0.050	54.040	-0.001	-0.020	70.070	0.000	0.003	71.463	0.000	0.006
210	49.053	-0.004	-0.054	54.039	-0.001	-0.021	70.069	-0.001	0.002	71.463	0.000	0.006
240	49.049	-0.004	-0.058	54.038	-0.001	-0.022	70.069	0.000	0.002	71.463	0.000	0.006
270	49.047	-0.002	-0.060	54.038	0.000	-0.022	70.069	0.000	0.002	71.463	0.000	0.006
300	49.044	-0.003	-0.063	54.037	-0.001	-0.023	70.069	0.000	0.002	71.463	0.000	0.006
330	49.042	-0.002	-0.065	54.037	0.000	-0.023	70.069	0.000	0.002	71.463	0.000	0.006
360	49.041	-0.001	-0.066	54.036	-0.001	-0.024	70.069	0.000	0.002	71.463	0.000	0.006
390	49.039	-0.002	-0.068	54.036	0.000	-0.024	70.069	0.000	0.002	71.463	0.000	0.006
420	49.037	-0.002	-0.070	54.035	-0.001	-0.025	70.069	0.000	0.002	71.463	0.000	0.006
450	49.036	-0.001	-0.071	54.034	-0.001	-0.026	70.069	0.000	0.002	71.463	0.000	0.006
480	49.035	-0.001	-0.072	54.034	0.000	-0.026	70.069	0.000	0.002	71.463	0.000	0.006
510	49.034	-0.001	-0.073	54.034	0.000	-0.026	70.069	0.000	0.002	71.463	0.000	0.006
540	49.033	-0.001	-0.074	54.034	0.000	-0.026	70.069	0.000	0.002	71.463	0.000	0.006
570	49.032	-0.001	-0.075	54.034	0.000	-0.026	70.069	0.000	0.002	71.463	0.000	0.006

DAY 6 — WET BULB (deg C) 13.4 — DRY BULB (deg C) 25.0 — RELATIVE HUMIDITY (%) 23.0 — DEW POINT (deg C) 3.0

ELAPSED TIME (sec)	EMPTY MILLIPORE (EM) WEIGHT (mgs)	EM WEIGHT CHANGE	EM CUMULATIVE CHANGE	LOADED MILLIPORE (LM) WEIGHT (mgs)	LM WEIGHT CHANGE	LM CUMULATIVE CHANGE	EMPTY FIBERGLASS (EF) WEIGHT (mgs)	EF WEIGHT CHANGE	EF CUMULATIVE CHANGE	LOADED FIBERGLASS (LF) WEIGHT (mgs)	LF WEIGHT CHANGE	LF CUMULATIVE CHANGE
30	49.041	0.000	0.000	54.057	0.000	0.000	70.063	0.000	0.000	71.456	0.000	0.000
60	49.026	-0.015	-0.015	54.044	-0.013	-0.013	70.066	0.003	0.003	71.462	0.006	0.006
90	49.020	-0.006	-0.021	54.037	-0.007	-0.020	70.066	0.000	0.003	71.462	0.000	0.006
120	49.016	-0.004	-0.025	54.032	-0.005	-0.025	70.066	0.000	0.003	71.462	0.000	0.006
150	49.014	-0.002	-0.027	54.028	-0.004	-0.029	70.066	0.000	0.003	71.462	0.000	0.006
180	49.011	-0.003	-0.030	54.025	-0.003	-0.032	70.066	0.000	0.003	71.462	0.000	0.006
210	49.009	-0.002	-0.032	54.022	-0.003	-0.035	70.066	0.000	0.003	71.462	0.000	0.006
240	49.008	-0.001	-0.033	54.021	-0.001	-0.036	70.065	-0.001	0.002	71.462	0.000	0.006
270	49.006	-0.002	-0.035	54.019	-0.002	-0.038	70.065	0.000	0.002	71.462	0.000	0.006
300	49.005	-0.001	-0.036	54.018	-0.001	-0.039	70.065	0.000	0.002	71.462	0.000	0.006
330	49.004	-0.001	-0.037	54.016	-0.002	-0.041	70.065	0.000	0.002	71.462	0.000	0.006
360	49.003	-0.001	-0.038	54.015	-0.001	-0.042	70.065	0.000	0.002	71.462	0.000	0.006
390	49.002	-0.001	-0.039	54.015	0.000	-0.042	70.065	0.000	0.002	71.462	0.000	0.006
420	49.001	-0.001	-0.040	54.014	-0.001	-0.043	70.065	0.000	0.002	71.462	0.000	0.006
450	49.001	0.000	-0.040	54.013	-0.001	-0.044	70.065	0.000	0.002	71.462	0.000	0.006
480	49.000	-0.001	-0.041	54.013	0.000	-0.044	70.065	0.000	0.002	71.462	0.000	0.006
510	49.000	0.000	-0.041	54.012	-0.001	-0.045	70.065	0.000	0.002	71.462	0.000	0.006
540	49.000	0.000	-0.041	54.012	0.000	-0.045	70.065	0.000	0.002	71.462	0.000	0.006
570	48.999	-0.001	-0.042	54.012	0.000	-0.045	70.065	0.000	0.002	71.462	0.000	0.006

Table 4 - Continued

DAY 7	WET BULB (deg C) 13.7	DRY BULB (deg C) 24.2
	RELATIVE HUMIDITY (%) 28.0	DEW POINT (deg C) 4.0

FILTER	EM1			LM1			EF1			LF1		
ELAPSED TIME (sec)	WEIGHT (mgs)	WEIGHT CHANGE	CUMULATIVE CHANGE	WEIGHT (mgs)	WEIGHT CHANGE	CUMULATIVE CHANGE	WEIGHT (mgs)	WEIGHT CHANGE	CUMULATIVE CHANGE	WEIGHT (mgs)	WEIGHT CHANGE	CUMULATIVE CHANGE
30	49.071	0.000	0.000	54.108	0.000	0.000	70.061	0.000	0.000	71.464	0.000	0.000
60	49.061	-0.010	-0.010	54.088	-0.020	-0.020	70.066	0.005	0.005	71.467	0.003	0.003
90	49.055	-0.006	-0.016	54.078	-0.010	-0.030	70.065	-0.001	0.004	71.467	0.000	0.003
120	49.052	-0.003	-0.019	54.072	-0.006	-0.036	70.066	0.001	0.005	71.466	-0.001	0.002
150	49.049	-0.003	-0.022	54.068	-0.004	-0.040	70.066	0.000	0.005	71.466	0.000	0.002
180	49.047	-0.002	-0.024	54.064	-0.004	-0.044	70.066	0.000	0.005	71.465	-0.001	0.001
210	49.046	-0.001	-0.025	54.061	-0.003	-0.047	70.066	0.000	0.005	71.465	0.000	0.001
240	49.044	-0.002	-0.027	54.059	-0.002	-0.049	70.066	0.000	0.005	71.465	0.000	0.001
270	49.043	-0.001	-0.028	54.057	-0.002	-0.051	70.065	-0.001	0.004	71.465	0.000	0.001
300	49.042	-0.001	-0.029	54.055	-0.002	-0.053	70.065	0.000	0.004	71.465	0.000	0.001
330	49.041	-0.001	-0.030	54.054	-0.001	-0.054	70.065	0.000	0.004	71.464	-0.001	0.000
360	49.040	-0.001	-0.031	54.052	-0.002	-0.056	70.065	0.000	0.004	71.464	0.000	0.000
390	49.039	-0.001	-0.032	54.051	-0.001	-0.057	70.065	0.000	0.004	71.464	0.000	0.000
420	49.038	-0.001	-0.033	54.050	-0.001	-0.058	70.065	0.000	0.004	71.464	0.000	0.000
450	49.038	0.000	-0.033	54.050	0.000	-0.058	70.065	0.000	0.004	71.464	0.000	0.000
480	49.037	-0.001	-0.034	54.049	-0.001	-0.059	70.065	0.000	0.004	71.464	0.000	0.000
510	49.037	0.000	-0.034	54.048	-0.001	-0.060	70.065	0.000	0.004	71.464	0.000	0.000
540	49.037	0.000	-0.034	54.048	0.000	-0.060	70.065	0.000	0.004	71.464	0.000	0.000
570	49.037	0.000	-0.034	54.048	0.000	-0.060	70.065	0.000	0.004	71.464	0.000	0.000

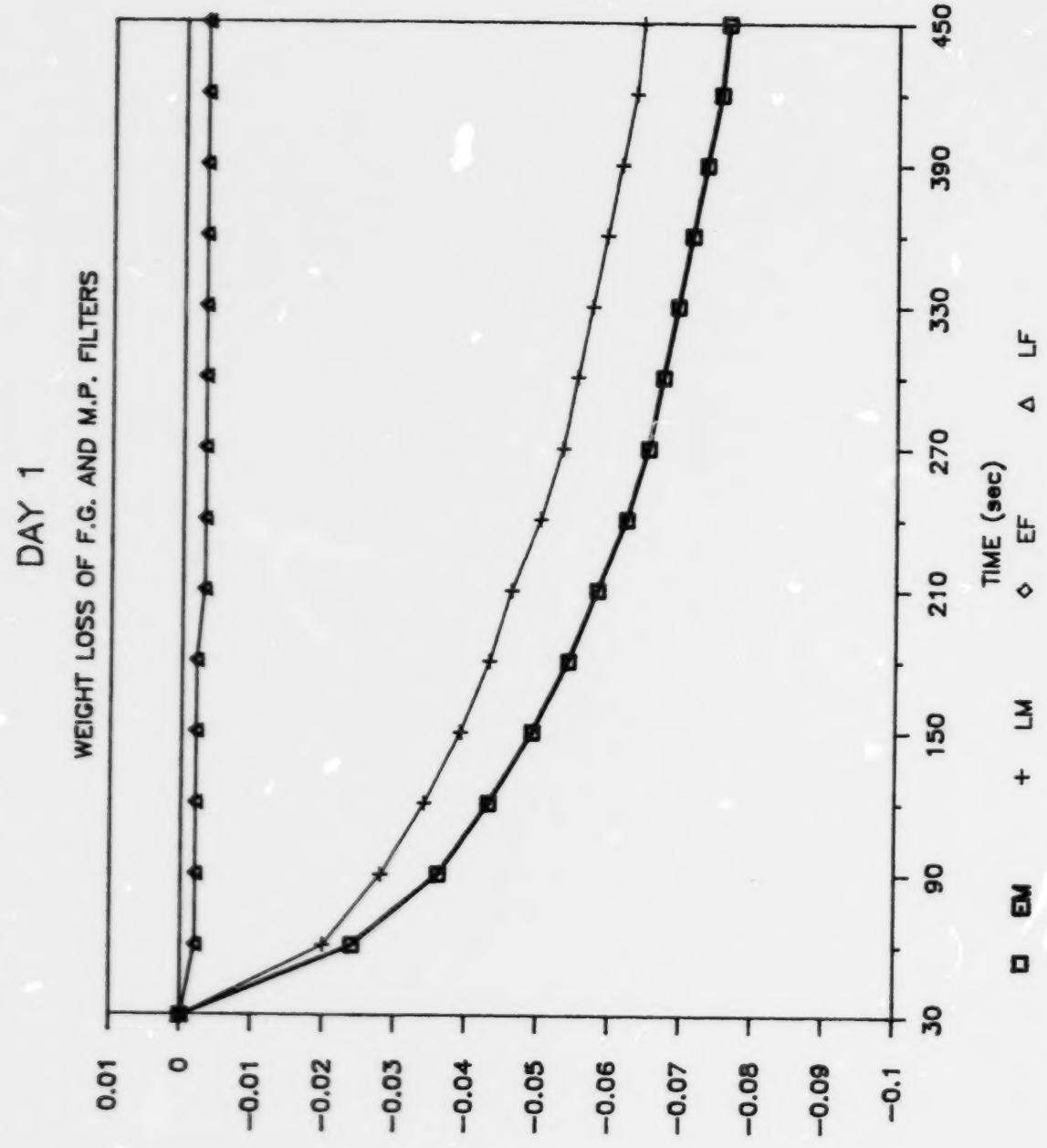


Figure 2A - Trial 2, day 1, comparison of fiberglass and millipore filters

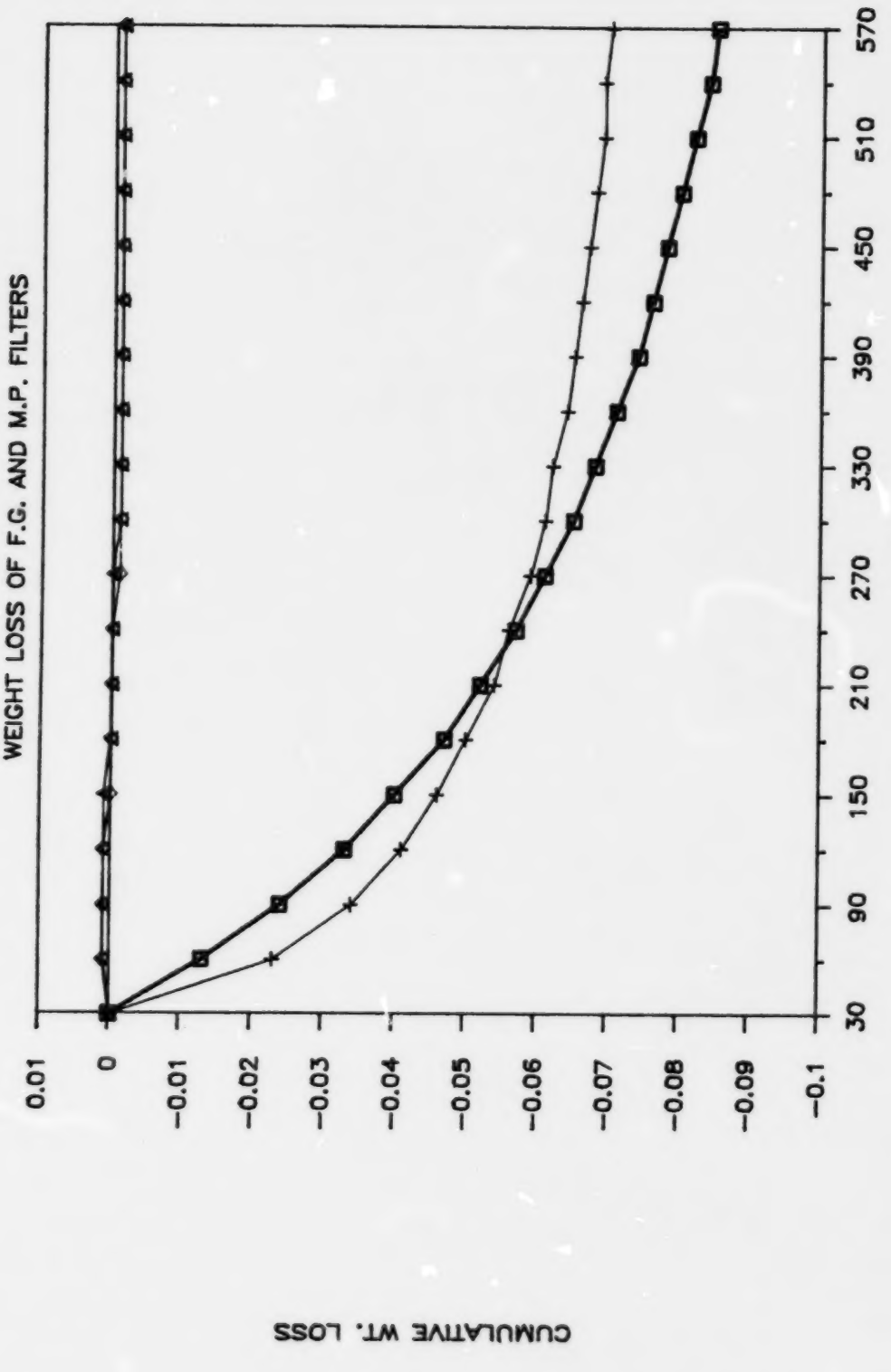


Figure 2B - Trial 2, day 2, comparison of fiberglass and millipore filters

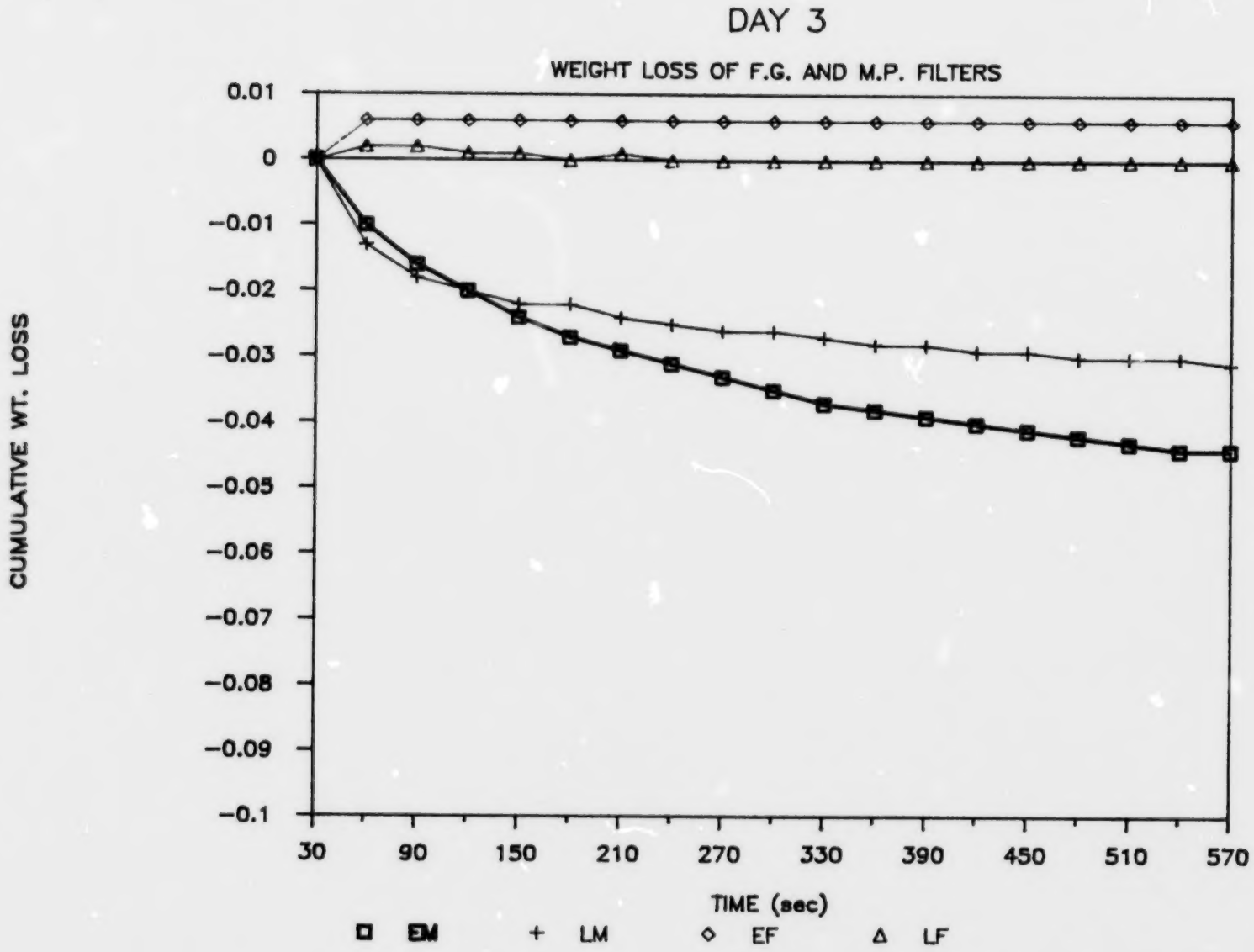


Figure 2C - Trial 2, day 3, comparison of fiberglass and millipore filters

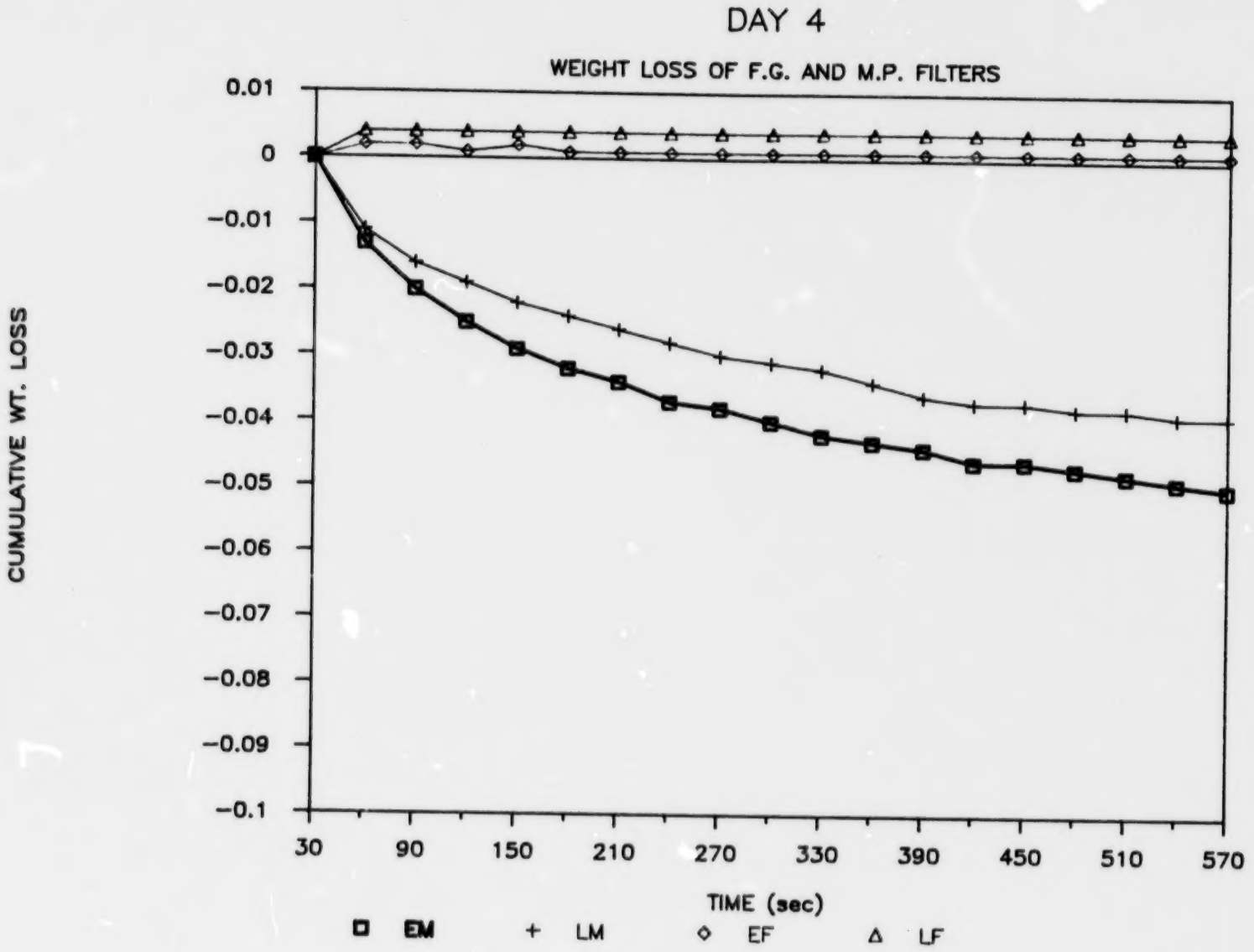


Figure 2D - Trial 2, day 4, comparison of fiberglass and millipore filters

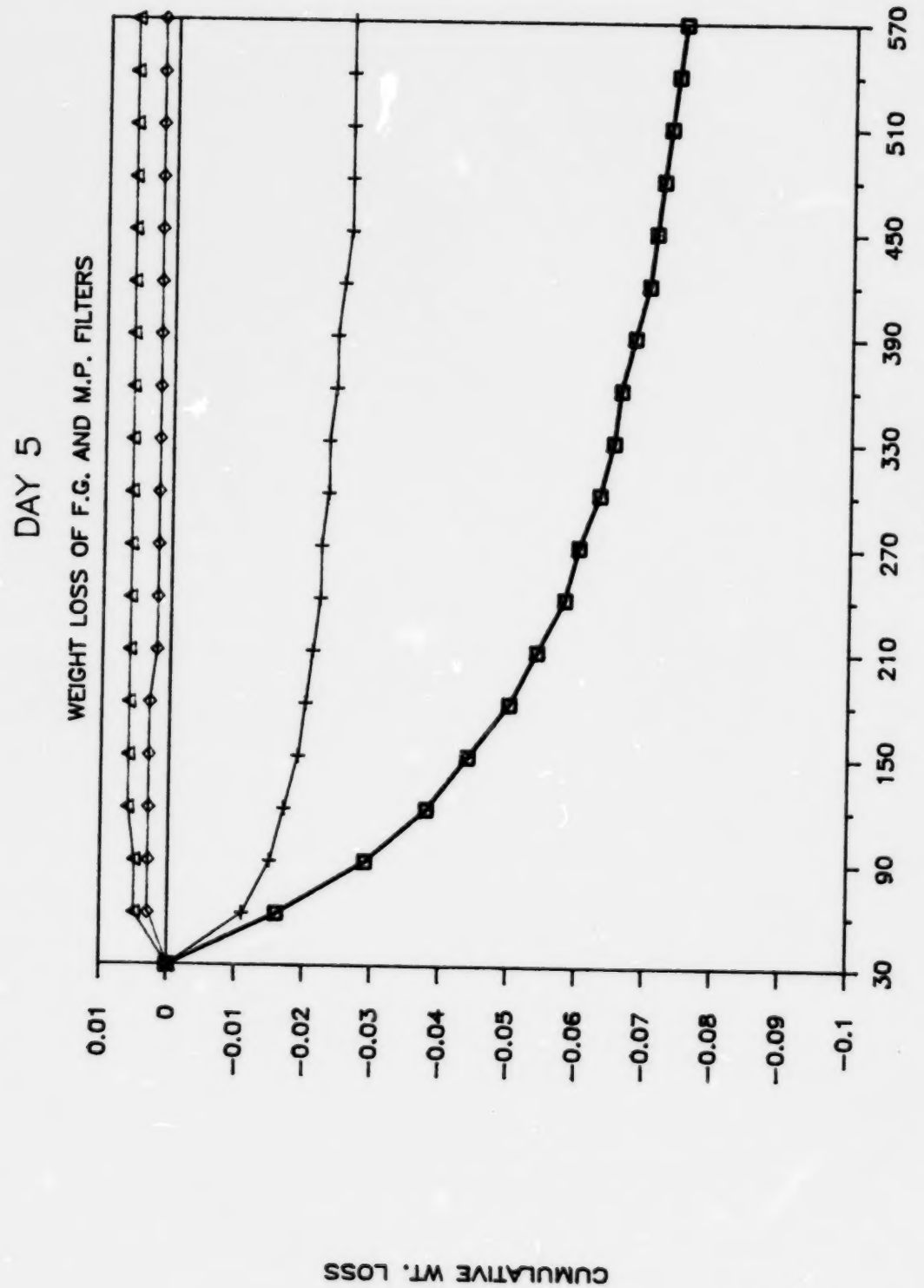


Figure 2E - Trial 2, day 5, comparison of fiberglass and millipore filters

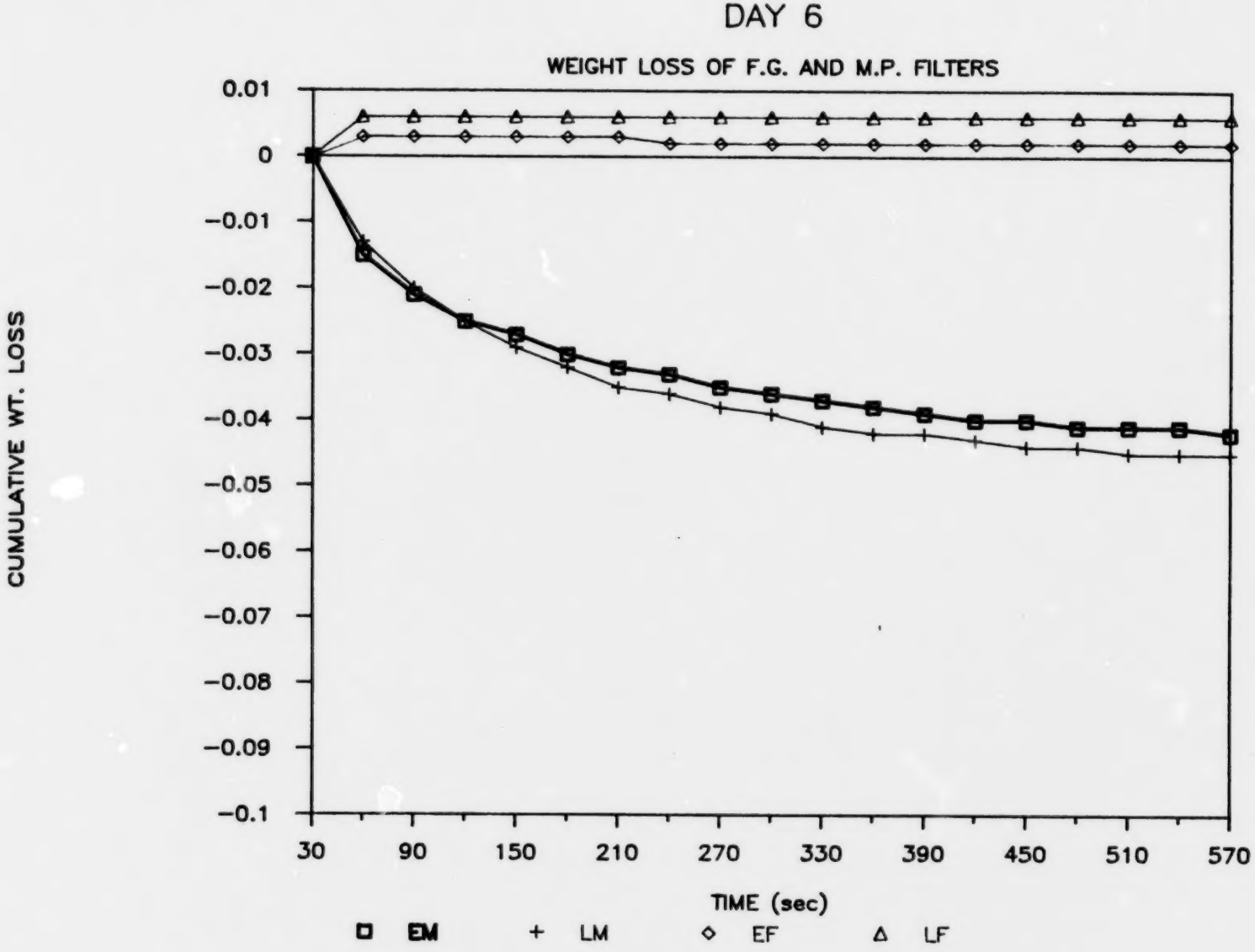


Figure 2F - Trial 2, day 6, comparison of fiberglass and millipore filters

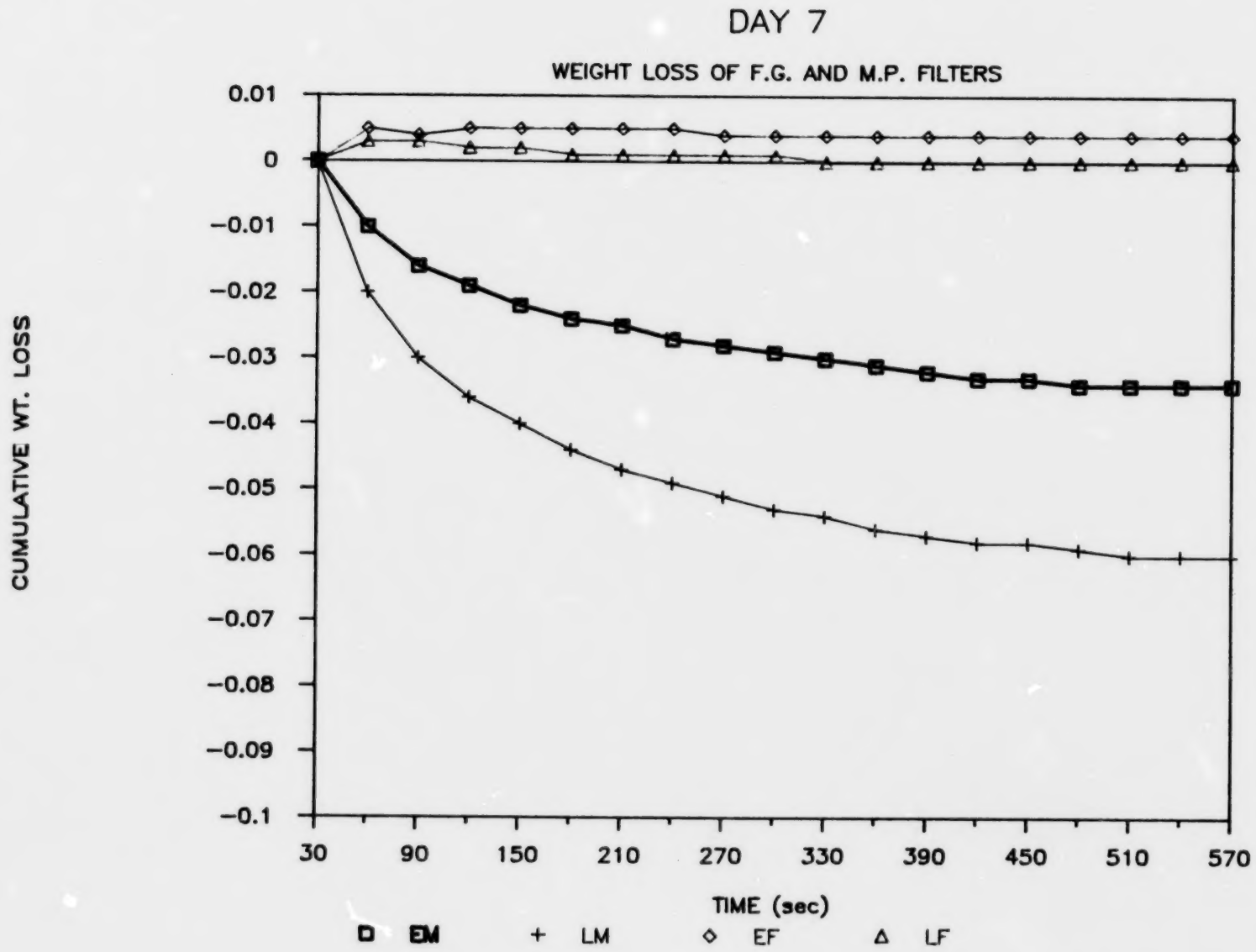


Figure 2G - Trial 2, day 7, comparison of fiberglass and millipore filters

humidity range would be needed. Such is the case in Trial 3 which follows with the corresponding Table 5 and Figures 3A-3E.

Static and handling problems with both fiberglass and millipore filter types are of little consequence as both seem to be unaffected by these problems if treated correctly.

TRIAL 3

Trial 3 consists of essentially the same criteria as Trial 2 except five filters were chosen: 1) millipore (mixed cellulose ester), 2) millipore, 3) teflon, 4) polycarbonate (nuclepore) and 5) fiberglass. Humidity was also more rigidily controlled to enable a better and wider spread. This allowed a better picture of filter characteristics over a wider environmental change. Table 5 and Figures 3A-3E note these effects and are summarized in the resulting discussion. A procedure 'C' of filter weighings and controlling conditions follows.

PROCEDURE 'C'

1) Set room humidity to desired conditions and temperature using humidifier or dehumidifier and air conditioner.
2) Ensure that there is no outside source of ventilation in the weighing room.
3) Set filters to be weighed out in controlled laboratory air for at least two hours before attempting to weigh.
4) Follow steps 2) to 6) of procedure 'A'.
5) Note the weight reading at the 30 second mark and every 30 second interval afterwards up to 10 minutes. Repeat for each of the five filters used.
6) Note all weight changes and construct Table 5 and Figures 3A-3E of cumulative weight change for each filter type.
7) Follow this procedure for three separate environmental conditions to achieve tables for different humidities with a wider range.

DISCUSSION OF PROCEDURE 'C' AND TRIAL 3

Considering the information obtained from Table 5 and the corresponding figures, it is evident that the millipore filters, Figures 3A-3B, have the greatest cumulative weight loss over the humidity range used. The

Table 5A - Day 1, comparison of weight change in five filter types at humidity 18%

DAY 1	WET BULB (deg C) 13.6			DRY BULB (deg C) 26.8											
	RELATIVE HUMIDITY (%) 18.0			DEW POINT (deg C) 1.0											
FILTER	A			B			C			D			E		
ELAPSED TIME (sec)	WEIGHT (mgs)	WEIGHT CHANGE	CUMULATIVE CHANGE	WEIGHT (mgs)	WEIGHT CHANGE	CUMULATIVE CHANGE	WEIGHT (mgs)	WEIGHT CHANGE	CUMULATIVE CHANGE	WEIGHT (mgs)	WEIGHT CHANGE	CUMULATIVE CHANGE	WEIGHT (mgs)	WEIGHT CHANGE	CUMULATIVE CHANGE
30	39.262	0.000	0.000	39.535	0.000	0.000	32.298	0.000	0.000	128.584	0.000	0.000	12.575	0.000	0.000
60	39.248	-0.014	-0.014	39.520	-0.015	-0.015	32.295	-0.003	-0.003	128.588	0.004	0.004	12.577	0.002	0.002
90	39.238	-0.010	-0.024	39.512	-0.008	-0.023	32.294	-0.001	-0.004	128.589	0.001	0.005	12.577	0.000	0.002
120	39.232	-0.006	-0.030	39.506	-0.006	-0.029	32.294	0.000	-0.004	128.590	0.001	0.006	12.577	0.000	0.002
150	39.226	-0.006	-0.036	39.502	-0.004	-0.033	32.294	0.000	-0.004	128.590	0.000	0.006	12.577	0.000	0.002
180	39.221	-0.005	-0.041	39.499	-0.003	-0.036	32.293	-0.001	-0.005	128.590	0.000	0.006	12.577	0.000	0.002
210	39.218	-0.003	-0.044	39.496	-0.003	-0.039	32.293	0.000	-0.005	128.590	0.000	0.006	12.577	0.000	0.002
240	39.215	-0.003	-0.047	39.495	-0.001	-0.040	32.293	0.000	-0.005	128.590	0.000	0.006	12.577	0.000	0.002
270	39.212	-0.003	-0.050	39.493	-0.002	-0.042	32.293	0.000	-0.005	128.590	0.000	0.006	12.577	0.000	0.002
300	39.210	-0.002	-0.052	39.491	-0.002	-0.044	32.293	0.000	-0.005	128.590	0.000	0.006	12.577	0.000	0.002
330	39.208	-0.002	-0.054	39.490	-0.001	-0.045	32.293	0.000	-0.005	128.590	0.000	0.006	12.577	0.000	0.002
360	39.207	-0.001	-0.055	39.489	-0.001	-0.046	32.293	0.000	-0.005	128.590	0.000	0.006	12.577	0.000	0.002
390	39.205	-0.002	-0.057	39.488	-0.001	-0.047	32.293	0.000	-0.005	128.590	0.000	0.006	12.577	0.000	0.002
420	39.204	-0.001	-0.058	39.487	-0.001	-0.048	32.293	0.000	-0.005	128.590	0.000	0.006	12.577	0.000	0.002

A Millipore
B Millipore
C Teflon
D Polycarbonate
E Fiberglass

Table 5B - Day 2, comparison of weight change in five filter types at humidity 53%

DAY 2				WET BULB (deg C) 17.8			DRY BULB (deg C) 24.1								
				RELATIVE HUMIDITY (%) 53.0			DEW POINT (deg C) 13.0								
FILTER	A			B			C			D			E		
ELAPSED TIME (sec)	WEIGHT (mgs)	WEIGHT CHANGE	CUMULATIVE CHANGE	WEIGHT (mgs)	WEIGHT CHANGE	CUMULATIVE CHANGE	WEIGHT (mgs)	WEIGHT CHANGE	CUMULATIVE CHANGE	WEIGHT (mgs)	WEIGHT CHANGE	CUMULATIVE CHANGE	WEIGHT (mgs)	WEIGHT CHANGE	CUMULATIVE CHANGE
30	39.546	0.000	0.000	39.781	0.000	0.000	32.286	0.000	0.000	128.566	0.000	0.000	12.577	0.000	0.000
60	39.520	-0.026	-0.026	39.761	-0.020	-0.020	32.287	0.001	0.001	128.567	0.001	0.001	12.579	0.002	0.002
90	39.507	-0.013	-0.039	39.752	-0.009	-0.029	32.288	0.001	0.002	128.567	0.000	0.001	12.579	0.000	0.002
120	39.499	-0.008	-0.047	39.748	-0.004	-0.033	32.288	0.000	0.002	128.567	0.000	0.001	12.579	0.000	0.002
150	39.493	-0.006	-0.053	39.745	-0.003	-0.036	32.288	0.000	0.002	128.567	0.000	0.001	12.579	0.000	0.002
180	39.489	-0.004	-0.057	39.744	-0.001	-0.037	32.288	0.000	0.002	128.566	-0.001	0.000	12.579	0.000	0.002
210	39.486	-0.003	-0.060	39.742	-0.002	-0.039	32.288	0.000	0.002	128.566	0.000	0.000	12.579	0.000	0.002
240	39.483	-0.003	-0.063	39.741	-0.001	-0.040	32.288	0.000	0.002	128.566	0.000	0.000	12.579	0.000	0.002
270	39.481	-0.002	-0.065	39.740	-0.001	-0.041	32.288	0.000	0.002	128.566	0.000	0.000	12.579	0.000	0.002
300	39.479	-0.002	-0.067	39.739	-0.001	-0.042	32.288	0.000	0.002	128.566	0.000	0.000	12.579	0.000	0.002
330	39.478	-0.001	-0.068	39.739	0.000	-0.042	32.288	0.000	0.002	128.566	0.000	0.000	12.579	0.000	0.002
360	39.476	-0.002	-0.070	39.738	-0.001	-0.043	32.288	0.000	0.002	128.566	0.000	0.000	12.579	0.000	0.002
390	39.475	-0.001	-0.071	39.738	0.000	-0.043	32.288	0.000	0.002	128.566	0.000	0.000	12.579	0.000	0.002
420	39.474	-0.001	-0.072	39.737	-0.001	-0.044	32.288	0.000	0.002	128.566	0.000	0.000	12.579	0.000	0.002

A Millipore
B Millipore
C Teflon
D Polycarbonate
E Fiberglass

Table 5C - Day 3, comparison of weight change in five filter types at humidity 87%

DAY 3				WET BULB (deg C) 21.8				DRY BULB (deg C) 23.5								
				RELATIVE HUMIDITY (%) 87.0				DEW POINT (deg C) 21.0								
FILTER	A			B			C			D			E			
ELAPSED TIME (sec)	WEIGHT (mgs)	WEIGHT CHANGE	CUMULATIVE CHANGE	WEIGHT (mgs)	WEIGHT CHANGE	CUMULATIVE CHANGE	WEIGHT (mgs)	WEIGHT CHANGE	CUMULATIVE CHANGE	WEIGHT (mgs)	WEIGHT CHANGE	CUMULATIVE CHANGE	WEIGHT (mgs)	WEIGHT CHANGE	CUMULATIVE CHANGE
30	40.228	0.000	0.000	40.496	0.000	0.000	32.283	0.000	0.000	128.840	0.000	0.000	12.595	0.000	0.000
60	40.182	-0.046	-0.046	40.456	-0.040	-0.040	32.282	-0.001	-0.001	128.821	-0.019	-0.019	12.597	0.002	0.002
90	40.157	-0.025	-0.071	40.435	-0.021	-0.061	32.283	0.001	0.000	128.816	-0.005	-0.024	12.597	0.000	0.002
120	40.143	-0.014	-0.085	40.422	-0.013	-0.074	32.282	-0.001	-0.001	128.814	-0.002	-0.026	12.597	0.000	0.002
150	40.132	-0.011	-0.096	40.414	-0.008	-0.082	32.282	0.000	-0.001	128.811	-0.003	-0.029	12.597	0.000	0.002
180	40.125	-0.007	-0.103	40.407	-0.007	-0.089	32.282	0.000	-0.001	128.809	-0.002	-0.031	12.597	0.000	0.002
210	40.119	-0.006	-0.109	40.401	-0.006	-0.095	32.282	0.000	-0.001	128.807	-0.002	-0.033	12.597	0.000	0.002
240	40.114	-0.005	-0.114	40.397	-0.004	-0.099	32.282	0.000	-0.001	128.806	-0.001	-0.034	12.597	0.000	0.002
270	40.110	-0.004	-0.118	40.393	-0.004	-0.103	32.282	0.000	-0.001	128.805	-0.001	-0.035	12.597	0.000	0.002
300	40.106	-0.004	-0.122	40.390	-0.003	-0.106	32.282	0.000	-0.001	128.804	-0.001	-0.036	12.597	0.000	0.002
330	40.103	-0.003	-0.125	40.386	-0.004	-0.110	32.282	0.000	-0.001	128.802	-0.002	-0.038	12.597	0.000	0.002
360	40.099	-0.004	-0.129	40.383	-0.003	-0.113	32.282	0.000	-0.001	128.801	-0.001	-0.039	12.597	0.000	0.002
390	40.097	-0.002	-0.131	40.381	-0.002	-0.115	32.282	0.000	-0.001	128.800	-0.001	-0.040	12.597	0.000	0.002
420	40.094	-0.003	-0.134	40.378	-0.003	-0.118	32.282	0.000	-0.001	128.799	-0.001	-0.041	12.597	0.000	0.002

A Millipore
B Millipore
C Teflon
D Polycarbonate
E Fiberglass

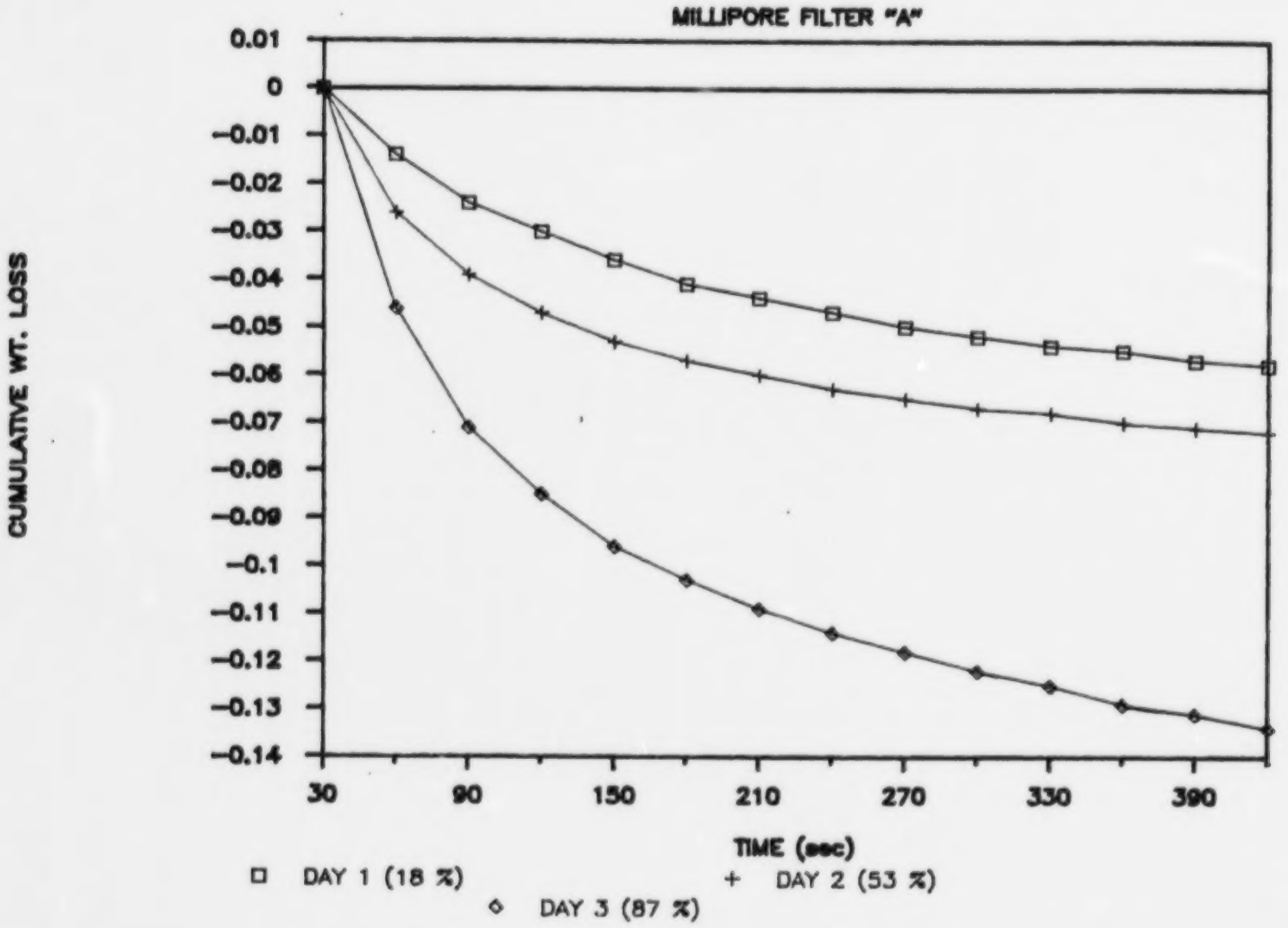


Figure 3A - Trial 3, examination of weight change over wide humidity ranges for five filters - millipore (mixed cellulose ester)

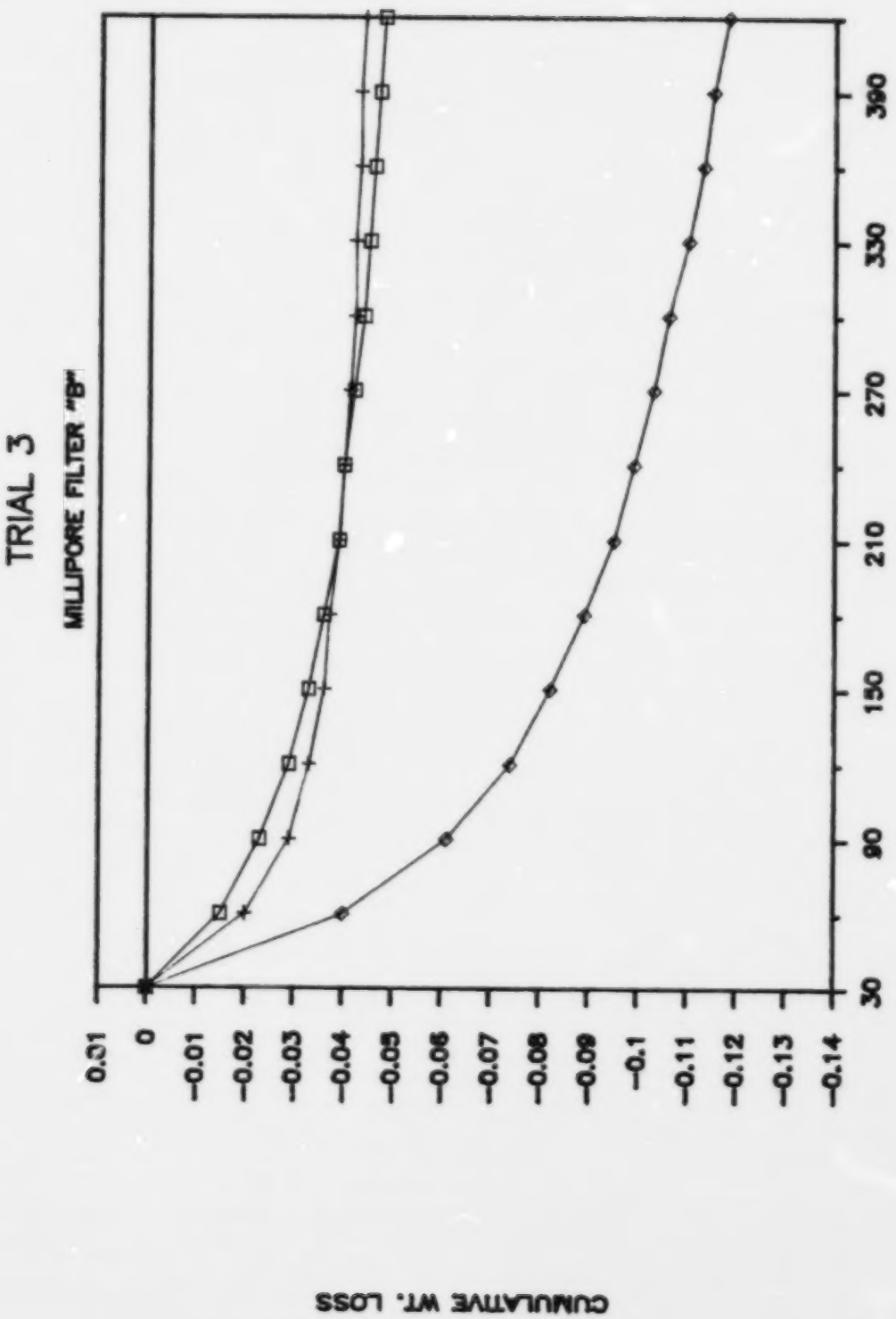


Figure 3B - Trial 3, examination of weight change over wide humidity ranges for five filters - millipore

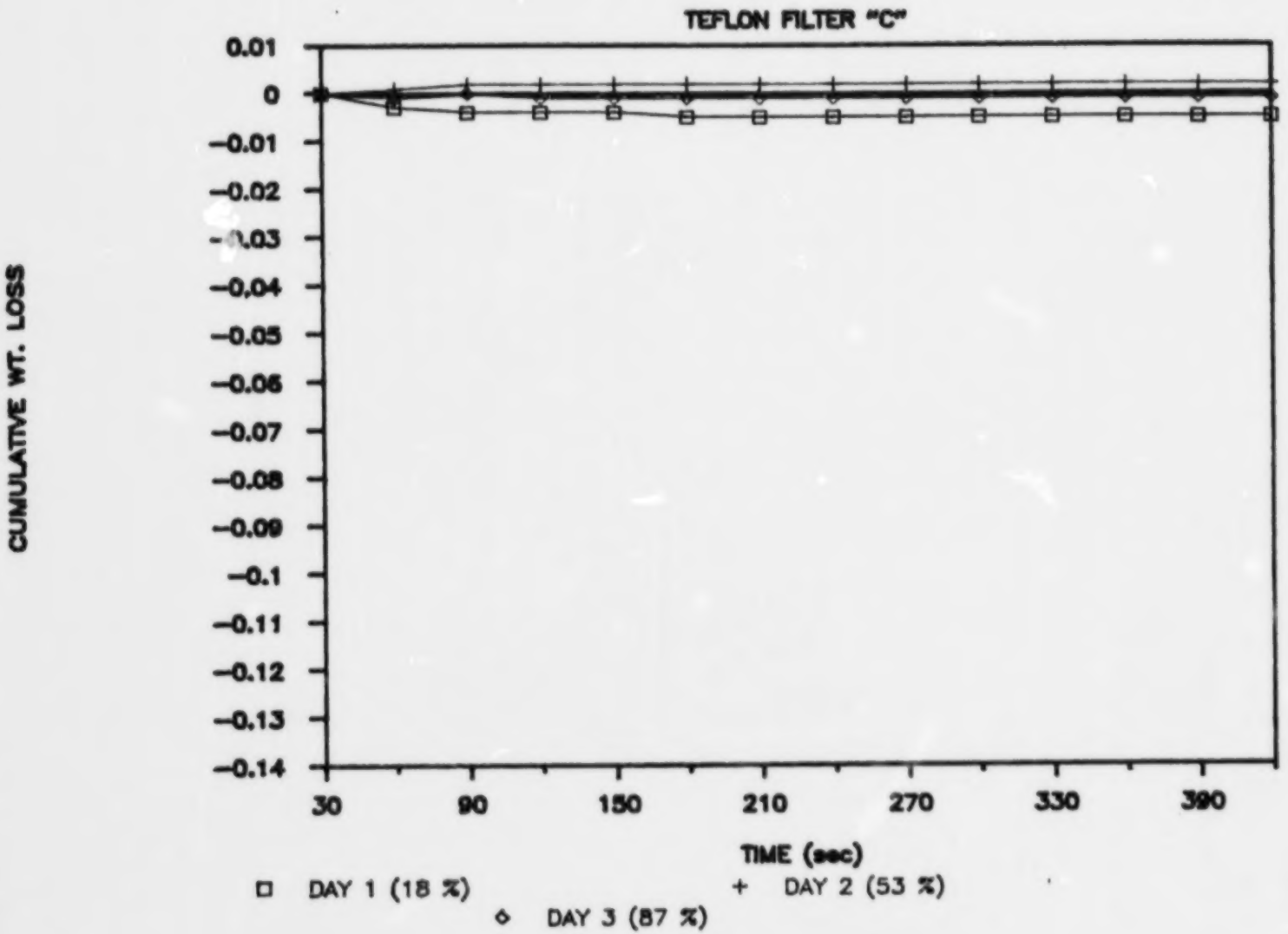


Figure 3C - Trial 3, examination of weight change over wide humidity ranges for five filters - teflon

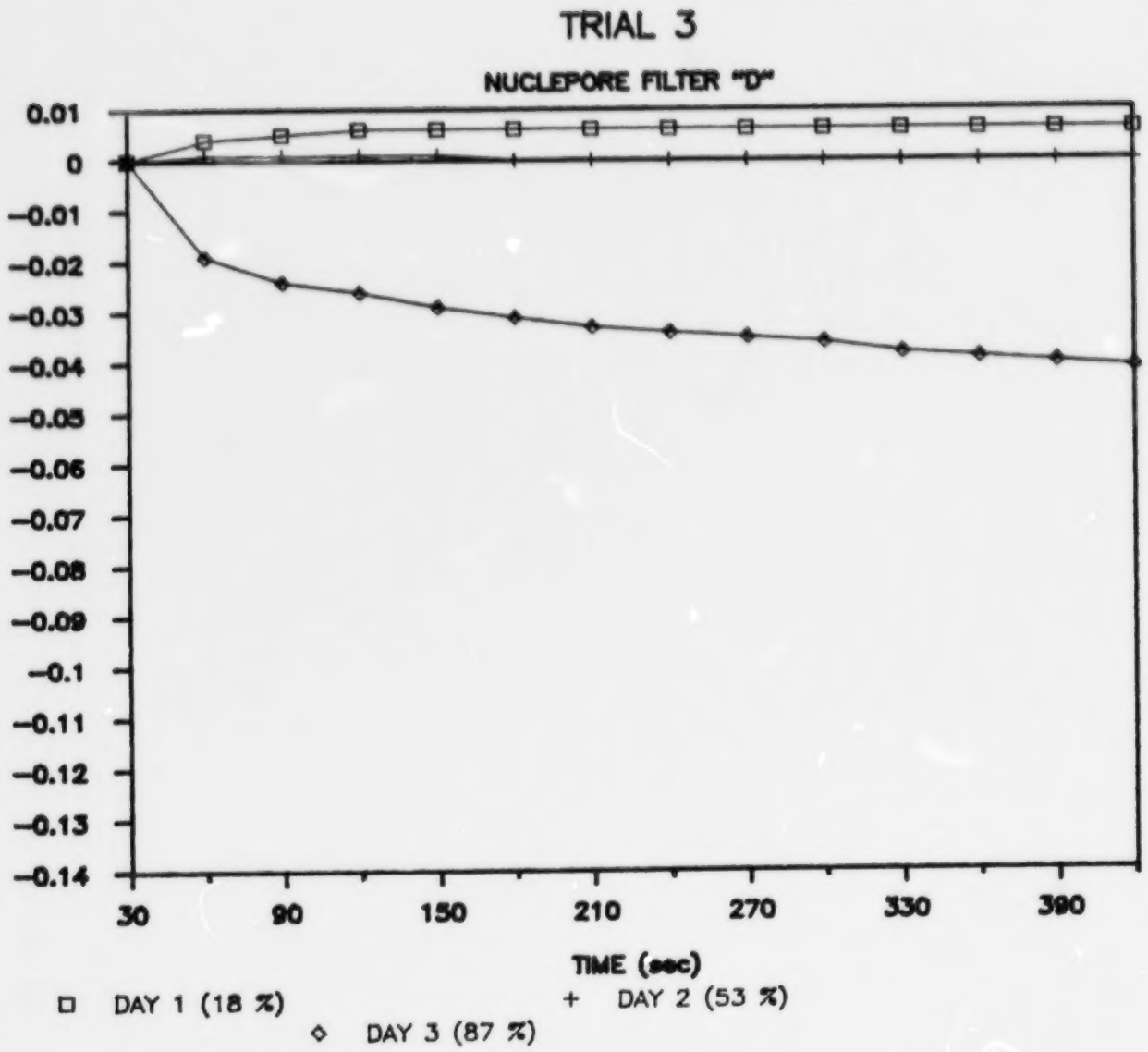
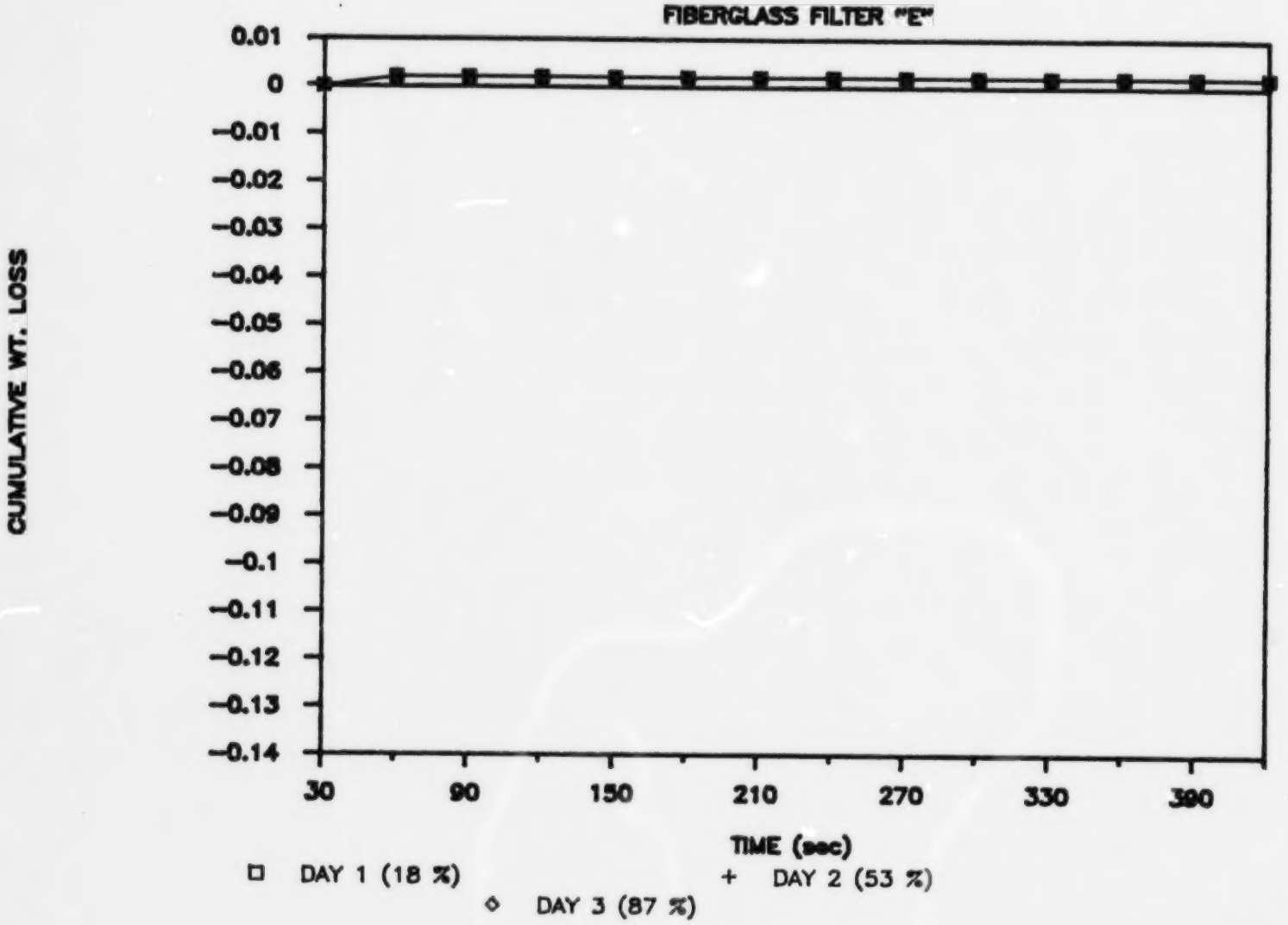


Figure 3D - Trial 3, examination of weight change over wide humidity ranges for five filters - polycarbonate (nuclepore)



Filter 3E - Trial 3, examination of weight change over wide humidity ranges for five filters - fiberglass

higher the relative humidity in the laboratory, the greater the apparent weight loss once placed in the balance chamber. The spread of this weight change is more evident with humidities from 53% to 80% than from 18% to 53%.

The polymer filter, teflon, indicates no significant relationship between change in weight and varying humidity conditions. This supports earlier statements made in Trial 2.

The polycarbonate filter, Figure 3D, indicates that its weight change is dependent on the humidity but only to a small, almost insignificant degree. If the humidity change were small, there would be no evident change in weight.

The fiberglass filter showed no corresponding change in cumulative weight over the weighing time for any of the corresponding humidities. However, as seen from Tables 5A, 5B and 5C there was a slight final total weight increase from the 18% relative humidity test to the 87% relative humidity test indicating some water absorption had taken place and therefore must be a slow process. Weighing errors with this type of filter should be very minimal.

CONCLUSIONS AND RECOMMENDATIONS

There are many types of errors related to gravimetric analysis when using filters as collection media. Controlling all these errors is difficult and proper techniques must be used. Some problems related to the weighing of respirable dust such as static or filter particles deposited onto the holder could make the weighing of the sample unreliable. All errors are controllable to a certain degree enabling the technician to obtain reliable data with minimal errors.

Trial 1 indicated that the filters most susceptible to changes from the laboratory environment to the Cahn 29 environment are the fiberglass and the cellulosic. Trial 2 further classifies these differences over a somewhat limited humidity range using loaded and empty filters but finds no real difference in the filter's response towards change in environmental conditions whether loaded with coal dust or not. Trial 3 further classifies all the types of filters used but pays special attention to millipore and fiberglass.

It indicated that changing environmental conditions, if not controlled, could render any form of gravimetric analysis unreliable.

In considering all the previous trials together, the one constant which seems to be the greatest form of error is the change in environmental conditions from the laboratory to the balance chamber. Weight changes experienced by filters are dependent on the type of filter and indeed the balance used. The Cahn 29 electrobalance establishes its own environment once the draft door is closed. The environment is dryer, perhaps due to the heat emitted from the balance electronics and therefore any filter which has previously absorbed water will begin to dry out and show a change in weight over a period of time. Millipore or cellulosic filters are most affected. In order to minimise effects of such as this, several remedies can be sought: use another electrobalance which does not exhibit this problem (e.g. a balance which has an environmentally controlled weighing compartment), control laboratory conditions to match the balance chamber conditions or designate a weighing time once the sample has been put on the pan inside the balance. This technique as shown in previous tables and figures will minimize errors especially where millipore filters are concerned.

Preliminary work with the Mettler AE-163 semi-microbalance has indicated that its environment is less of a factor and will not affect results adversly. Although the balance is less sensitive, it does however have a greater weighing range giving the added advantage of being able to weigh the filter in the holder thereby elminating the problem of filter material sticking or adhering to the holder.

Each filter's particular characteristic should be known and each should be treated with the utmost care possible in order to do proper gravimetric analysis. The following is a recommended procedure to be used in the gravimetric analysis of coal mine dust. It is felt that if this procedure is followed, errors will be reduced and more reliable reproducibleresults can be obtained.

CBCRL ROUTINE PROCEDURE

PRIOR TO FIELD SURVEY

1) Set room environment with air conditioner, humidifier and dehumidifier combination to the following: humidity 25-30%, temperature 20-25°C.

Once the setting is selected there should be no changes made over the entire weighing process.

2) Set f...rs and blanks out in conditioned air for at least two hours prior to weighing in order that they may climatize with the environment.
3) Calibrate balances according to balance manuals.
4) Determine relative humidity, dew point and temperatures exactly.
5) Weigh all filters by type. Weigh fiberglass filters together with fiberglass blanks and millipore filters with the millipore blanks. There should be an absolute minimum of two blanks of each type of filter used. Blank weighings should be interspersed within filter weighings in order to spot potential changes in conditions.
6) Grasp each filter to be weighed by its edge with a pair of tongs and pass it through the static master ionizing unit to remove any static charges.
7) Place the filter on the tared electrobalance and start the stopwatch. Consult Table 6 below in order to determine the time at which to take the weight. A minimum time of two minutes is recommended.

Table 6 - Recommended balance time (sec)

Filter Type	Cahn 29	Mettler AE-163
Fiberglass	120	120
Millipore	300	120
Polyvinyl Chloride	120	120
Polycarbonate	120	120
Silver Membrane	120	120
Teflon	120	120

Determine initial weight (WSi) at the specified time for the sampling filter.

Determine initial weight (WBi) at the specified time for the blank filter.

8) At this time the filter and holder may be assembled and placed on the Mettler AE-163 for the specified time to determine empty filter and holder weight (for later comparison work). Record this weight (WHi).

9) Blanks are placed in containers until the final weighing is to take place.

AFTER COMPLETION OF SURVEY

10) Set environmental conditions in weighing room to the specific conditions set in 1) of this procedure.
11) Place filters and holders out in laboratory environment for a minimum of two hours.
12) Calibrate electro and semi-microbalances according to manuals.
13) Weigh filters and holders on the Mettler AE-163 balance in order to determine the final weight of the filter and holder (WHf).
14) Remove filters from holders by using a pair of tongs. Carefully grasp the edge of the filter and remove it from the holder.
15) Carefully inspect filter holder to see if any sample or filter material has stuck to the holder, if so carefully brush the material onto the filter with a soft brush and note this in the weighing log.
16) Weigh all filters by type. Weigh fiberglass filters with the weighing of fiberglass blanks and millipore filters with the millipore blanks. There should be a minimum of two blanks of each type of filter used. Blank weighings should be interspersed within filter weighings in order to spot potential changes in conditions.
17) Grasp each filter to be weighed by its edge with a pair of tongs and pass it through the static master ionizing unit to remove any static charges.
18) Place the filter on the tared electrobalance and start the stopwatch. Consult Table 6 in order to determine the time at which to take the weight. A minimum time of two minutes is recommended.
19) Note the weight at the time indicated in the table above and this weight represents the final weight (WSf) for the filter plus the sample or (WBf) for the final weight of the blanks.
20) Procedure for calculating corrected sample weight:

    Weight of coal dust W total (Cahn 29 electrobalance) = WSf-WSi-WBf-WBi

    Weight of coal dust W total (Mett. semi-microbalance) = WHf-WHi-WBf-WBi

Calculation of coal dust concentrations:

Conc. = [W total (Cahn) mg/(Pump run time min. x Flow Rate of Pump 1/min.)] x 1000 $1/m^3$ = mg/m^3

Conc. = [W total (Mett.) mg/(Pump run time min. x Flow Rate of Pump 1/min.)] x 1000 $1/m^3$ = mg/m^3

REFERENCES

1. Hwang, J.C.Y. and Stewart, D.B. "CBCRL's respirable dust research program December 1984"; CANMET Division Report ERP/CRL 84-85(TR); 1984.
2. Hwang, C.Y., Kennedy, D.J. and Bonnell, G.W. "Respirable dust measurements made at Lingan Colliery during the period December 1984 - March 1985: Part I"; CANMET Division Report ERP/CRL 85-68(CF).
3. Hwang, C.Y. "Measurements of respirable dust concentrations by using various samplers in an underground coal mine"; CANMET Division Report 86-105(J,OP); 1986.
4. Hwang, C.Y., Bonnell, G.W., Corbett, G.R., MacNeil, C.H., Young, D.A., O'Leary, L.S. and O'Brien, D.J. "Respirable dust measurements made at Prince Colliery during the period December 1985 - June 1986"; CANMET Division Report ERP/CRL 86-131(CF); 1986.
5. O'Brien, D.J. "Procedures of portal-to-portal surveys" to be reported elsewhere.
6. Young, D.A. "Pump calibration procedures used at CBCRL" to be reported elsewhere.
7. Millipore catalogue and purchasing guide 1978-1979.
8. Nuclepore Corporation 1984 catalogue.